





THE JOURNAL OF RESEARCH ON THE LEPIDOPTERA

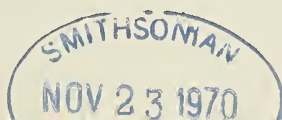
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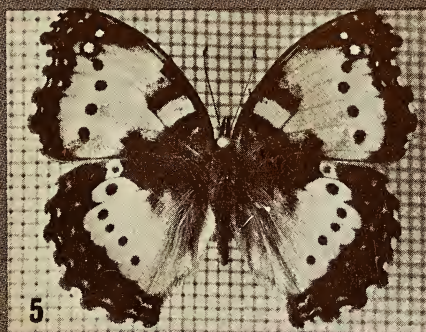
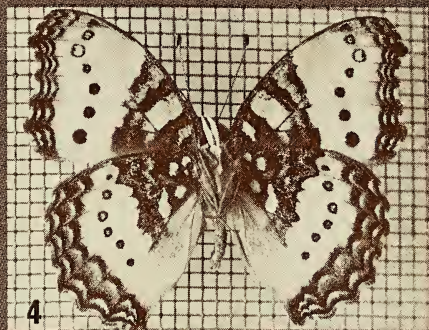
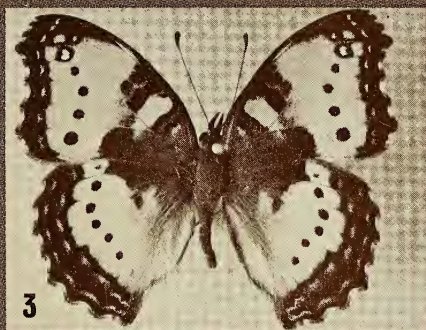
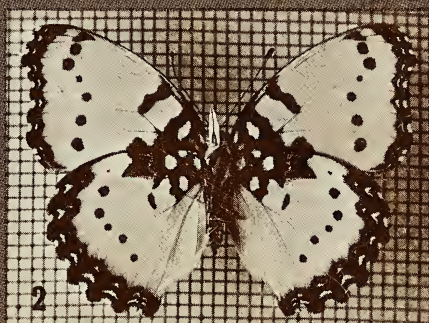
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CONTROLLED ENVIRONMENT EXPERIMENTS WITH *PRECIS OCTAVIA* CRAM. (NYMPHALIDAE)

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INTRODUCTION

"SEASONAL DIMORPHISM" HAS LONG been of great interest to lepidopterists because the insects exhibiting this phenomenon did not conform with the early accepted principles of systematics which were based on pigmentation. Only in the early years of this century were certain previously distinct species shown to be two extreme forms of the same "seasonally dimorphic" species. This was the case with *Precis octavia* Cramer, an African butterfly. As a result of such examples, the principles of systematics were revised and based on taxonomic differences of microscopic organs instead of on pigmentation alone.

Since then, many studies have been made of the palearctic "seasonally dimorphic" species but little experimentation has been carried out on tropical species.

The tropical genus *Precis* undoubtedly exhibits the most striking differences between seasonal forms. The characters generally affected are size, wing shape (especially in tailed species) and wing colour and markings of both surfaces.

Two races of *Precis octavia* occur in Africa. The northwestern race *octavia* distributed from Sierra Leone, Congo, Ethiopia, to Somalia, and the southern race *sesamus* ranging from Angola, Kenya, Rhodesia to the Cape of South Africa. In the southern race, form *natalensis* Staudinger is predominantly red in colour on both surfaces and form *sesamus* Trimen is predominantly blue on the upperside and dark brown/black on the underside.

TABLE 1
METEOROLOGICAL DATA
KAREN, NAIROBI AREA

MONTH	Rain inches (Mean)	Temperature °C (Mean)	Max. °C (Mean)	Min. °C (Mean)	Mean Hours Sun per day	Mean % Sun per day	Relative Humidity 8.30-14.30
JANUARY	1.47	20.2	25.6	15.0	9.7	40.4	57
FEBRUARY	2.13	21.1	27.8	6.1	9.6	40.0	56
MARCH	5.27	21.1	28.9	10.0	8.3	34.6	61
APRIL	7.71	20.7	28.3	11.1	7.1	29.6	69
MAY	5.17	19.6	27.8	10.6	6.3	26.3	71
JUNE	1.62	18.0	27.8	5.6	4.5	18.8	69
JULY	0.59	17.1	25.6	5.0	4.1	17.1	68
AUGUST	0.97	17.4	25.6	4.4	4.4	18.3	67
SEPTEMBER	0.92	19.0	27.8	5.6	6.5	27.1	59
OCTOBER	1.93	20.1	27.8	7.8	7.4	30.8	61
NOVEMBER	4.02	20.0	24.4	12.2	7.2	30.0	66
DECEMBER	2.49	19.7	25.6	11.1	8.5	35.4	63

Total 34.29 19.5 :-----: :-----:
 Mean 1964-1965 Kabete
 :-----: Karen Met. Stn.
 Mean 39 years

Minimum Temperature recorded at Karen 3.9°C.

The southern race *P. octavia sesamus* is locally common in Kenya. In the Karen area, fifteen miles from Nairobi, the butterflies may be seen flying along the edges of the Ngong Forest and in the late afternoon can often be seen assembling under the eaves of houses and in small stone quarries where they shelter for the night.

Larval stages occur throughout the Ngong, Karen and Kikuyu areas of Kenya where *Coleus forskohlii*, the food plant, is used by African smallholders as a hedge plant.

The majority of butterflies seen are either of form *natalensis* or of form *sesamus*. Intermediates can sometimes be taken but these are uncommon (Butler 1901, Clarke & Dickson 1953, Pinhey 1949).

Two generations normally occur in a year. During September to November f. *sesamus* is in the majority and from January to April f. *natalensis*, but there is a normal overlap of survivors.

NATURAL ENVIRONMENTAL CONDITIONS

Although Karen is only 90 miles south of the equator, it is at an altitude of 6000 ft. and temperatures are moderate. The duration of daylight is a fairly constant 12 hours per day.

In Table 1 can be seen meteorological data for the Karen area. The information is quoted here as being typical of an area of Kenya in which *P. octavia sesamus* is found in both of its seasonal forms.

It is not at first obvious from the information on Table 1 that there is a "cold" season and a "warm" season in this area. There is little difference between the maximum temperatures for each month and also little difference between the minimum temperatures. These figures are somewhat misleading because during the period June to August, the higher temperatures are only maintained for a short time each day. During the period December to January the higher temperatures are maintained for the majority of the day and low temperatures are only achieved for very short periods. It is for this reason that I have included figures of mean daily sunlight duration and also expressed sunlight as a percentage.

Kenya has two rainy seasons, the "short rains" during October to November, and the "long rains" of March to May. The mean monthly daytime relative humidity varies little. When one considers that the larvae feed on the flush of vegetation which occurs at the end of, and immediately after the rains, it can be seen that the late instars and pupae of the two generations ex-

TABLE 2

Precis octavia (Cram)Parent - Wild ♀ f. natalensis (July/Aug. 1965)

Temperature °C	Humidity	Hours Light/Day	Initial No. Larvae	f. sesamus	f. miotoni	f. susani	f. nairobicus	f. transiens	f. natalensis
Uncontrolled	95	12	20	0	0	0	1	1	12
Uncontrolled	Uncontrolled	12	5	0	0	0	2	1	1
Uncontrolled	30	12	20	2	0	4	4	5	2

Parents - f. natalensis ♀ x f. natalensis ♂ (Oct.-Dec. 1965)

32 *	30	0	20	0	0	0	0	0	0	0
27	30	2 1/2	20	0	0	0	0	0	0	13
27	95	0	40	0	0	0	0	1	0	19
27	30	0	20	0	0	0	0	0	0	8
24 + 3	95	12	20	0	0	1	6	6	2	2
24 + 3	30	12	20	0	0	1	5	2	2	2
21 + 3	95	12	20	2	0	7	2	0	0	0
21 + 3	Uncontrolled*	0	20	3	1	1	3	5	0	0
21 + 3	30	0	20	5	0	6	4	0	0	0
Uncontrolled	Uncontrolled	12	20	0	0	0	2	2	9	9

* Complete mortality resulting from extreme temperature.

perience the two differences in temperature and light intensity mentioned here.

The above information tends to rule out humidity as a factor concerned with the production of the two colour forms of this butterfly. I decided, nevertheless, to include humidity as one of the variable factors in a number of simple experiments.

EXPERIMENTAL

Towards the beginning of this century, Dorfmeister, Merri-field, Standfuss, Suffert and Weismann showed that in the family Nymphalidae, heat causes light colouration and cold causes dark colouration.

Experiments were performed on *P. octavia* by Marshall (1902) but definite conclusions were not forthcoming. Marshall suggested that the two extreme forms always alternate with each other and that intermediate forms can be produced by shock treatment or abnormal conditions. (Rothschild 1918). Clark & Dickson (1957) in their study of the life cycle of *P. octavia*, did perform experiments but reported that f. *sesamus* was not produced under the warmer conditions of Durban.

During 1965, 1966 and 1967, I reared numbers of *P. octavia* *sesamus* under controlled environmental conditions in three different laboratories.

Food Supply I had previously shown with English species of Pieridae and Nymphalidae that supply of food only affects the size of the imago. Prior to these experiments, larvae of *Precis archesia* Cram. and *P. octavia* were starved during their fifth instar and specimens of only 30 mm. were produced. Larvae which were given a plentiful supply of fresh food throughout their larval life produced specimens which averaged 50 mm. Consequently fresh supplies of food were provided daily in these experiments.

Light Observations on larvae in the field showed that they tend to keep to the shadier sections of their food plant and avoid strong sunlight. This is not surprising because temperatures in direct sunlight are very high in Karen. Light intensity is not likely therefore to be a factor concerned in the production of seasonal forms. However, other research workers have suggested that duration of light may play an important part in the production of seasonal forms of *Araschnia levana* L. of Europe. Despite the fact that the duration of daylight is a constant 12 hours per day throughout the year in East Africa where both extreme forms occur, I decided to include three variables of light. These were zero light, 12 hours per day, and constant light.

TABLE 3

Precis octavia (Cram)

Parents wild ♂ f. sesamus x bred ♀ f. sesamus (Sept. 1966 - Oct. 1967)

Temperature °C	Humidity	Hours Light/Day	Initial No. Larvae	f. sesamus	f. miontoni	f. susani	f. nairohicus	f. transiens	f. natalensis
30°	95	24	10	0	0	0	0	0	7
30°	30	24	10	0	0	0	0	0	5
30°	95	12	10	0	0	0	0	0	8
30°	30	0	10	0	0	0	0	0	6
27°	95	12	10	0	0	0	0	1	6
19°	95	12	20	2	1	0	0	0	0
16	95	0	10	5	0	0	0	0	0
16	30	0	10	3	0	0	0	0	0
16	Uncon- trolled	0	10	6	0	0	0	0	0
5 *	95	0	10	0	0	0	0	0	0
5 *	30	0	10	0	0	0	0	0	0
Uncontrolled	Uncon- trolled	12	20	14	0	2	2	0	0

* Complete mortality resulting from extreme temperature.

Temperature & Humidity Earlier experiments were performed in cabinets which lacked modern facilities. Humidity was maintained at a low level using crystals of silica gel which were replaced daily. High humidity was maintained using water bottles with cotton wool wicks. Only the higher temperatures could be maintained at a constant level using electrical heating.

Later, certain of the experiments were performed in modern constant environment rooms. Here, the control of humidity and temperature was facilitated by modern humidifying, cooling and heating equipment.

In all experiments the egg and first instar larvae were kept under moderate conditions, and larvae were introduced into more extreme conditions at the second instar. This procedure was found to greatly reduce early mortality.

Numbers of individuals reaching maturity were not as high as I intended. Mortalities from disease were often severe especially under conditions of high humidity, and on two occasions all culture insects were completely destroyed by safari ants *Dorylus nigricans* Illig. This drastically reduced the numbers of insects available for the experiments and made a properly replicated trial impossible.

RESULTS

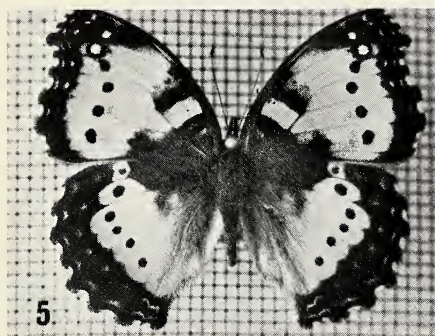
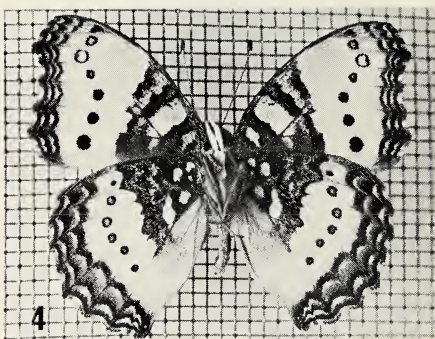
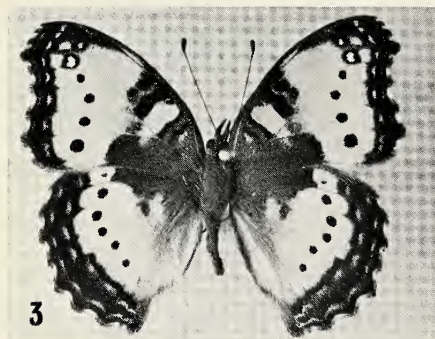
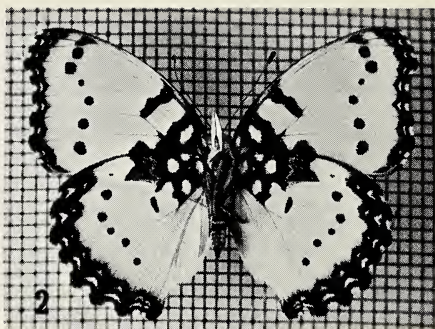
Extreme variation in pigmentation was recorded in larval, pupal and adult stages.

Throughout the experiments the majority of larvae exhibited five instars. In one instance however, several larvae in the same cage exhibited seven instars. The cage concerned was maintained at a temperature of 21°C with no humidity control and in complete darkness. The reason for the occurrence of the extra instars is not known. Clarke & Dickson (1953) also record the occurrence of five, six and seven instar larvae and suggest that it forms a mechanism for staggering emergence of adults.

Head capsules were collected and mounted from each cage and these completely verify the observations.

Pigmentation of Larvae

Early instars did not vary their pigmentation according to the differing environmental conditions. It soon became apparent that the colour of the fifth instar larvae varied according to temperature. At the lower temperatures the larvae were black and at the higher temperatures they were orange, without exception. The larvae which exhibited seven instars showed variations in pigmentation in the seventh instar only.



Figs. 1-6 *Precis octavia* Cram.

Upperside, left; underside, right. 1 and 2, *f. natalensis* Staudinger ♂; 3 and 4, *f. transiens* Wichgraf ♂; 5 and 6, *f. transiens* Wichgraf ♂.

The situation was further complicated by the discovery that there were two strains of larvae which exhibited different colour forms. The earlier experiments of 1965 (Table 2) produced all "plain" larvae and the experiments of 1966-67 (Table 3) produced a mixture of "plain" and "striped" larvae. The appearance of a second type of larva in the second series of experiments corresponded with the introduction of another strain of adult (derived from the same locality).

The two types of larvae and the way in which the pigmentation of the final instars is changed with temperature, are described here.

Plain Larvae — Final Instar

21°C. and below

Almost entirely velvety black with metallic blue bases to the spines. Two yellowish patches occur in each thoracic segment, situated one on each side of the mid-dorsal line. These patches may be absent at low temperatures.

24°C.

As above but the yellowish patches extend the entire length of the larva along the mid-dorsal line and the lateral ridge. 27-32°C.

Larvae entirely orange-yellow with areas of red at the bases of black spines.

Striped Larvae Final Instar

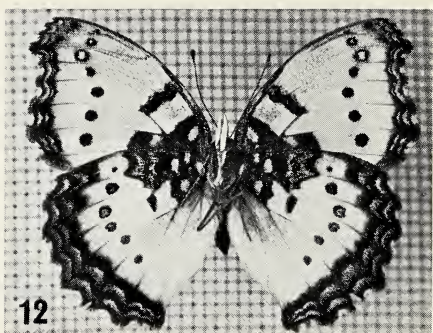
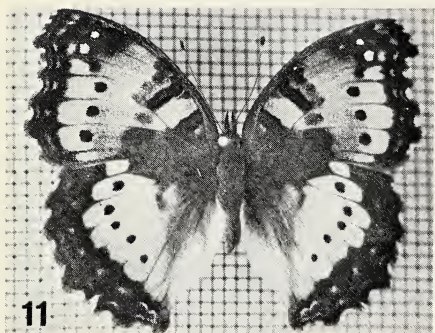
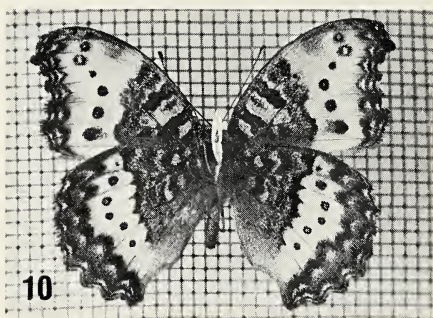
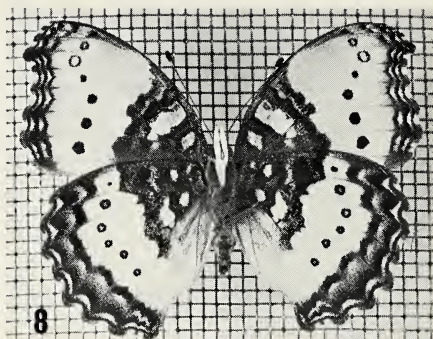
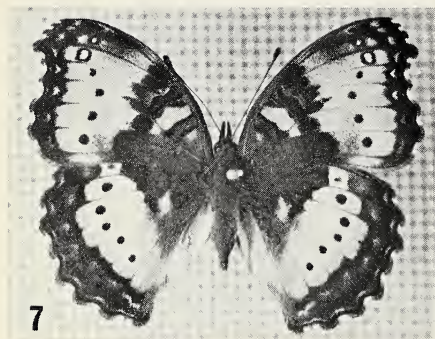
21°C. and below

Ground colour black broken in each abdominal segment by stripes of yellow which pass from the mid-dorsal line down to the lateral ridge. Two of the yellow stripes are narrow and positioned adjacent to the intersegmental membranes, i.e. they are positioned at the anterior and posterior of each segment. The third yellow stripe is broader and positioned slightly anterior to the centre of each segment. As in the plain larvae, these also have yellow patches dorsally situated in the thoracic segments.

24°C.

The black areas become slightly tinted with orange especially the areas adjacent to the mid-dorsal line and lateral ridge. 27-32°C.

The black areas become entirely orange-red in colour.



Figs. 7-12. *Precis octavia* Cram.

Upperside, left; underside, right. 7 and 8, *f. transiens* Wichgraf ♀; 9 and 10, *f. transiens* Wichgraf ♂; 11 and 12, *f. nairobiensis* (f. nov.) ♂ Paratype.

Pigmentation of Pupae

Pupae occurred in four different colour forms which were in no way related to colour forms of larvae or adults. Also they did not correspond with any of the environmental factors or background colour of their cages. The four colour forms were dark brown, light brown, mottled and gold.

(Colour Plate 1, Fig. 4)

Pigmentation of Adults

Results obtained are summarised in Tables 2 and 3. These indicate that neither the light duration nor humidity affect the pigmentation of the adult. Temperature changes almost exactly correspond to the differences in pigmentation of the adults. At the higher temperatures, 27-32°C. *f. natalensis* was produced, and at the lower temperatures, 10-16°C. *f. sesamus* was produced irrespective of the form of the parent or sex of the individual.

A complete range of intermediate forms was bred at temperatures between 18-24°C. A selection of these is illustrated here in Figures 3-26. Some of these intermediate forms do not correspond with the description of *f. transiens* (Wichgraf 1918). I therefore make descriptive notes here on three new forms as well as the three forms already described.

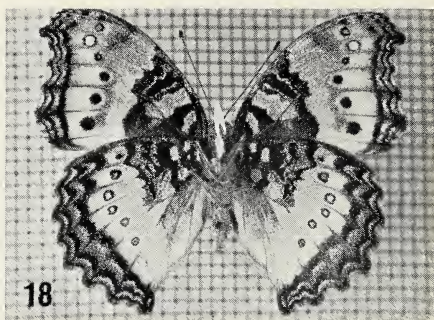
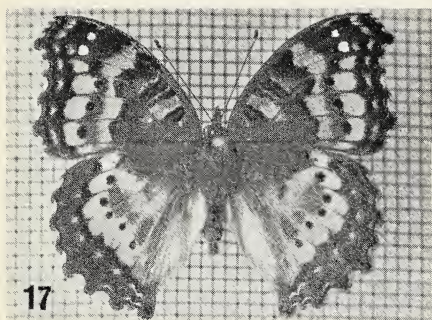
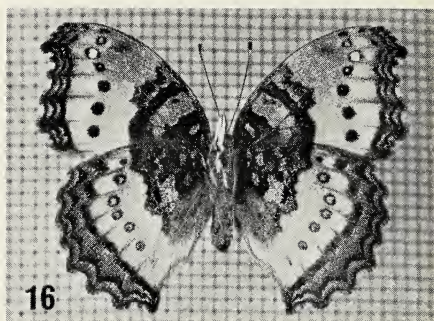
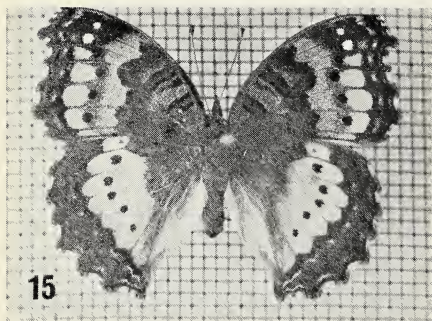
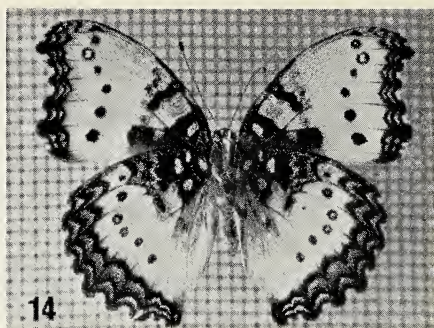
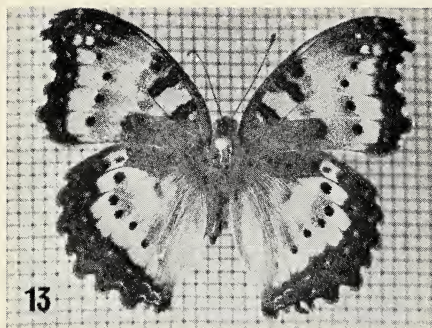
Many lepidopterists feel that separate names should not be given to temperature forms. In this case I feel that because of the extreme differences within this species, the various forms should be named and described for ease of reference.

DESCRIPTIVE

1. *f. natalensis* Staudinger (Figs. 1-2)

Upperside. Ground colour strongly red with a black margin along the outer border. All discal spots are black and do not possess pupils. Those of cellules 5 and 6 are larger. No blue scales are present on the proximal side of the discal spots. A dark brown area passes from the base of the forewing to half way along the inner margin and connects with the first transverse bar of the cell but not the second.

Underside. Black areas occur at the bases of all wings. These black areas contain four orange patches on the hindwings. Ground colour pinkish red and wings are not demarcated into halves.



Figs. 13-18. *Precis octavia* Cram.

Upperside, left; underside, right. 13 and 14, f. *nairobicus* (f. nov.) Holotype ♂; 15 and 16, f. *susani* (f. nov.) Paratype ♀; 17 and 18, f. *susani* (f. nov.) Holotype ♂.

Note. Some specimens at first sight appear to be of *f. natalensis* but possess blue or more rarely white pupils to the discal spots of cellules 5 and 6. It will be found on close examination with a lens that blue scales are present on the proximal side of discal spots of cellules 1 and 2 of the forewing. These specimens are therefore of *f. transiens* Wichgraf. Generally all specimens with blue or white pupils to discal spots in cellules 5 and 6 are intermediates or *f. sesamus*.

2. *f. transiens* Wichgraf (Figs. 3-10)

Upperside. Ground colour red with a black margin along outer border. Small areas of blue scales occur on the proximal side of the discal spots in cellules 1 and 2 only of the forewing. Discal spots of cellules 5 and 6 of the forewing with white or blue pupils. Dark brown areas occur on the distal side of the second transverse bar of the cell of the forewing and these may or may not connect up with those of the inner margin.

Underside. Basal half of each wing tends to be demarcated from the distal half, and is dark brown/black in colour compared with the pink/red of the distal half. Marginal band broad with two rows of blue streaks on upperside and underside.

3. *f. nairobiicus*. *f. nov.* Holotype ♂ Allotype ♀

Bred from wild-caught ♀ Karen, Nairobi, Kenya.

Paratypes 9 ♂ 5 ♀, as Holotype and Allotype, in author's collection.

Upperside. As in *f. transiens* but blue areas occur on the proximal side of all the discal spots of the forewing and may also occur on the hindwing. These blue areas remain separate in each cellule and do not join together. Discal spots in cellules 5 and 6 of the forewing possess white pupils.

Underside. As in *f. transiens*.

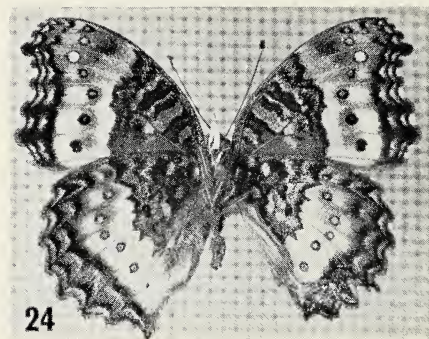
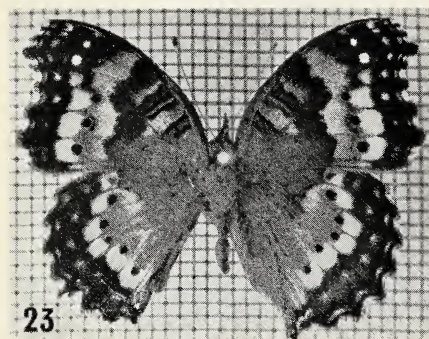
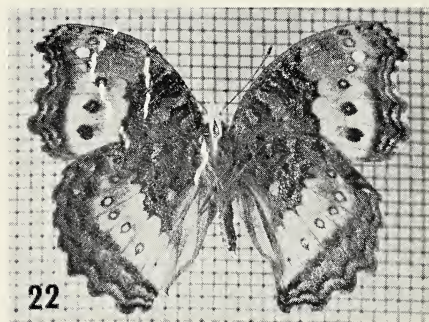
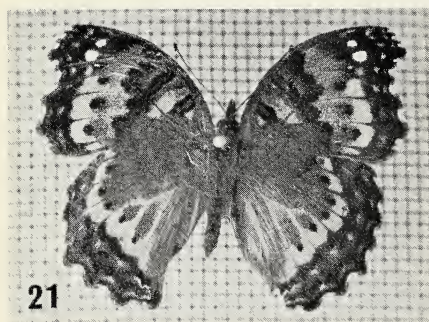
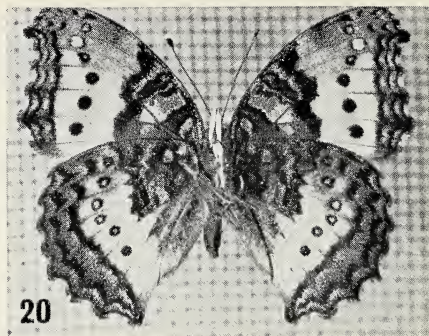
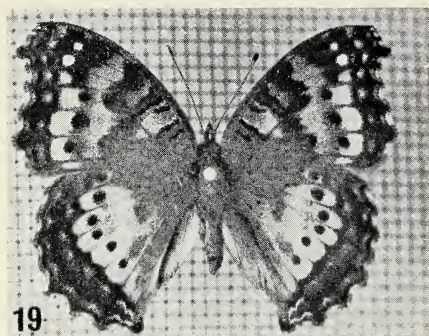
4. *f. susani* *f. nov.* (Figs. 15-24)

Holotype ♂

Allotype ♀ Bred from wild-caught ♀ Karen, Nairobi, Kenya

Paratypes — 10 ♂ 7 ♀ as Holotype and Allotype, in author's collection.

Upperside. Ground colour red. Blue areas are present on the proximal side of all discal spots of the forewings and hindwing. In the forewings the blue areas in cellules 1-6 join together to form a bar. In the hindwings the blue areas tend to be oval and separate in each cellule, but in more extreme forms the blue areas unite here also. The areas of dark brown positioned dis-

Figs. 19-24. *Precis octavia* Cram.

Upperside, left; underside, right. 19 and 20, *f. susani* (f. nov.) Allotype ♀.
21 and 22, *f. susani* (f. nov.) Paratype ♂; 23 and 24, *f. susani* (f. nov.)
Paratype ♂.

tally to the second transverse bar of the cell of the forewing, join up with those running along the inner margin from the base.

Underside. Basal half of all wings sharply defined and bounded by a curved dentate line. The distal halves remain pinkish red in colour but the basal halves are dark brown/black.

5. *f. miotoni* f. nov. (Figs. 26-26)

Holotype ♂ In author's collection.

Paratype 1 ♂ Both bred from insects wild — caught in Karen, Nairobi, Kenya. Obviously intermediate between *f. sesamus* and *f. susani* but the areas of blue scales on the proximal side of the discal spots are diffused amongst the red scales instead of occurring in definite areas. This results in an overall lilac appearance. The area discal to the discal spots of cellules 1-4 remains red traversed by the dark veins 2-4. Discal spots in cellules 5 and 6 of the forewings possess white pupils.

6. *f. sesamus* Trimen (Figs. 27-28)

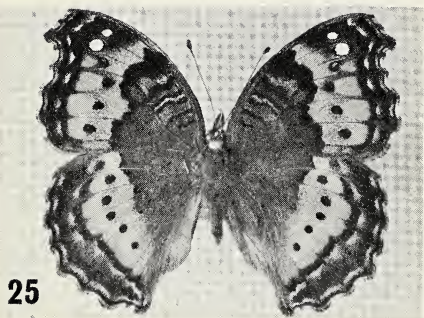
Upperside. Ground colour blue with a tendency to purple. Forewings project slightly at the extremity of vein 6. Discal spots in cellules 1-4 black, in cellules 5-6 white pupilled. Distal to the submarginal spots of cellules 1-4 are four large red spots. Marginal band broad with two rows of blue streaks. Basal half of all wings dark brown.

Underside. Ground colour dark brown/black with perhaps traces of pinkish red in cellules 2-3. The basal half of each wing is bounded by a curved dentate line. Discal spots in cellules 5-6 possess white pupils. Discal spots in cellules 1-4 with or without white pupils. Note. In extreme forms the discal spot in cellule 4 of the upperside of the forewing also has a white pupil (Fig. 29) and lines are more dentate especially those demarcating the basal from the distal halves of the wings. The forewings project at the extremity of vein 6 and the ground colour is more of a definite blue.

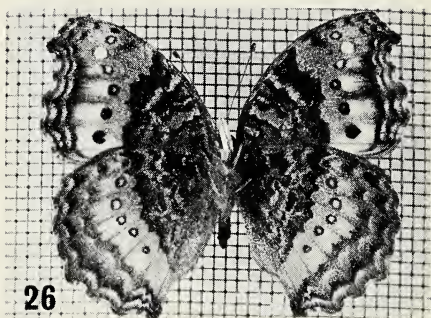
SUMMARY & CONCLUSIONS

A brief distribution of *Precis octavia sesamus* in Africa is given. Meteorological data is quoted for an area of Kenya in which both extreme forms of the butterfly occur. Previous studies of this species are mentioned.

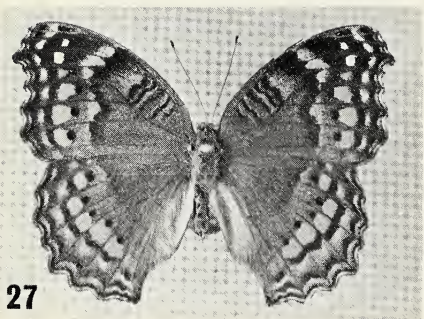
Experiments are outlined in which numbers of *Precis octavia sesamus* were reared under controlled environmental conditions. The environmental factors controlled were humidity, light dur-



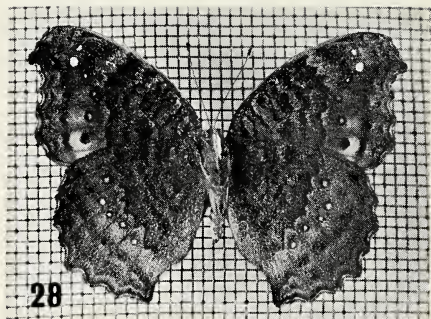
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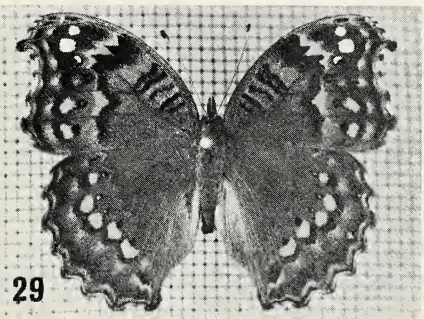
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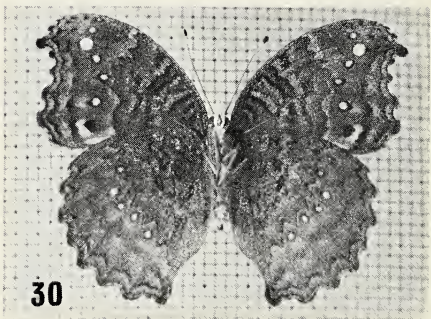
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29



30

Figs. 25-30. *Precis octavia* Cram.
 Upperside, left; underside, right. 25 and 26, f. *miotoni* (f. nov.) Holotype ♂; 27 and 28, f. *sesamus* Trimen ♂; 29 and 30, f. *sesamus* Trimen ♀.

ation and temperature. (Food supply had previously been shown to be unrelated to pigment changes.)

Although numbers of insects were not large, the author considers the evidence sufficient to conclude that:

- a) The only environmental factor to affect the pigmentation of *P. octavia sesamus* is temperature.
- b) Temperature, as well as controlling the pigmentation of the imago, also controls the pigmentation of the final instar larva.
- c) The pigmentation of the pupa is unrelated to temperature.

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EDITOR'S NOTE: It is planned at some time in the near future to illustrate the larvae, pupae and adult forms in color.

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ECOLOGICAL AND DISTRIBUTIONAL NOTES ON *EREBIA DISA* (SATYRIDAE) IN CENTRAL CANADA

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Erebia disa (Thunberg) is a circumpolar species with several geographic subspecies including *mancinus* Doubleday which occurs in central Canada west to the Rockies. As late as 1936 (Warren), *E. disa* was not known to occur east of the Alberta Rockies in North America; however, Brooks (1942) recorded it from Aweme and Gillam, Manitoba and Riotte (1959) recorded it from five localities in extreme northern Ontario east to Smoky Falls. More recently its range has been found to be more extensive and complete. Riotte (1962) recorded it at Hymers, Ontario, near the Minnesota border; John Polusny and C. S. Quelch (*in litt.*) captured specimens in Southwest Manitoba at Sandilands Provincial Forest during June 1967; I captured three specimens at Riding Mountain National Park, Manitoba on 25 June 1967; and during June and July of 1968, Patrick J. Conway and I filled in many gaps in the range by discovering eight colonies in Manitoba and Ontario (figure 1.).

I found *Erebia disa* restricted to black spruce/sphagnum bogs and especially those bogs having tall, dense stands of pure spruce. In this habitat, *disa* was encountered among the larger spruce, but a few strays were observed in more open bog areas or along roads bordering bogs. Ehrlich (1956) found that *E. disa* in Alaska always appeared to be associated with spruce forest, but noted strays in sedge marshes or crossing roads. Ehrlich also noted numbers of *disa* sucking moisture from a damp road at mile 1316 on the Alaska Highway. In the Palearctic Region, *E. disa* is usually depicted as being associated with marshes, however, in Norway, Sheldon (1913) found that *disa* preferred a wet "moor" overgrown with *vaccinium* rather than nearby swamps and marshes.

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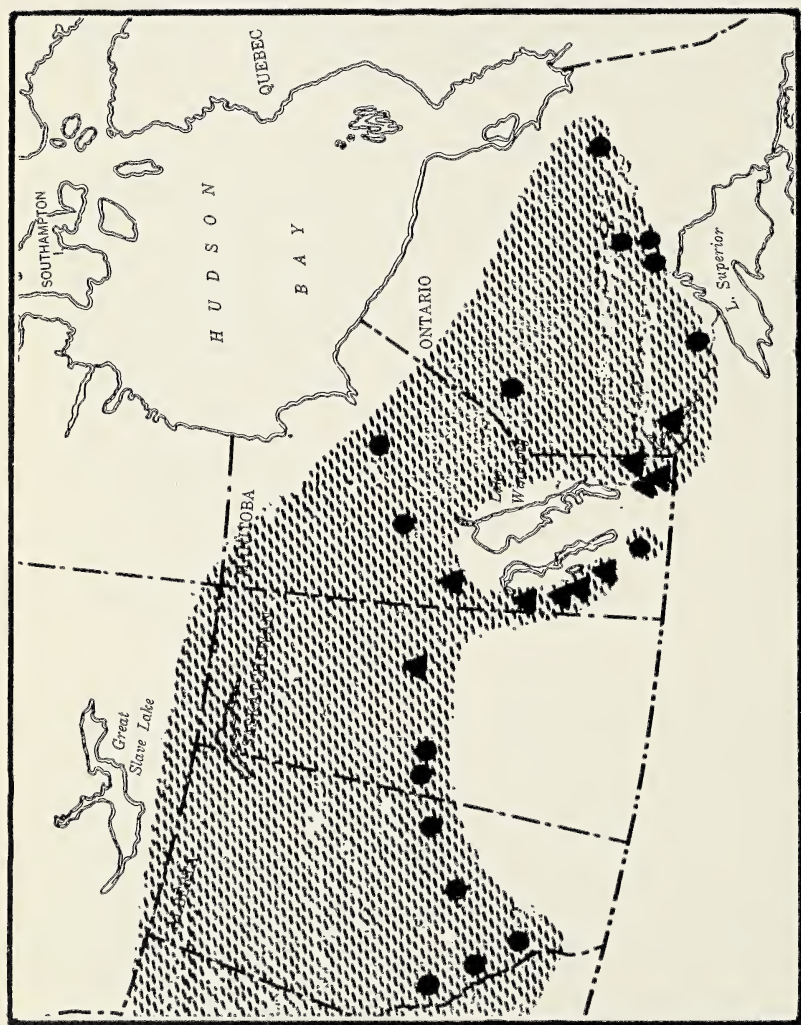


Figure 1. Central Canada showing expected range of *Erebia disa mancinus* Doubleday (shaded area), previously known localities (circles) and newly reported localities (triangles).

Erebia disa has a decided tendency to shun bright sunlight and, for the most part, will fly in the morning before 11:00 A.M. and again in the evening after 4:00 P.M. On cloudy days they will fly through the noon hours, but on sunny days can be flushed with difficulty from foliage at the base of spruce trees. *E. disa* flies slow and steady about three feet off of the ground and prefers lighting in partial sunlight on low foliage at the base of spruce trees. The slow flight can be deceptive as unlike *Oeneis jutta* (Hubner), which darts back and forth in rapid flight, *disa* will maintain a linear direction through a bog and can quickly outdistance a collector. Because *Erebia disa* is a forest dweller, I thought that it might exhibit some degree of territorialism, as was noted in forest dwelling *Oeneis* (Masters and Sorensen, 1969), but territorial behavior was not detected. In Satyridae, territorialism and "hilltopping" seem to be closely related; Shields (1968) includes *Erebia* among a list of genera that "are apparently devoid of hilltopping species."

Oeneis jutta was the only other species that always seemed to be associated with *Erebia disa* (also noted by Ehrlich, 1956).

Erebia disa might have a biennial flight as do several Palearctic *Erebia* including *E. claudina* (Bkh.) and *E. ligea* (L.). The late Richard J. Fitch, formerly of Rivercourse, Saskatchewan, first collected *E. disa* in spruce bogs near Harlan, Saskatchewan in 1942 and thereafter only seemed to encounter it in even numbered years (Masters, 1968). While *E. disa* has now been taken in consecutive years in the same area in Manitoba—it has not been retaken in the same bogs. In fact, I found it wanting in 1968 in the same Riding Mountain bog where I had found it in 1967 and John Polusny (*in litt.*) was unable to retake it in 1968 in the Sandilands bog where he found it the previous year. The pattern with biennial *Erebia* in Europe has nearby colonies randomly alternating with each other on the year of flight and it appears that this might be the case with *Erebia disa mancinus*. This is quite different from the pattern in *biennial* appearing *Oeneis* where populations over extensive areas are on the same cycle and alternation occurs only across a natural barrier such as a mountain range or desert.

Erebia disa has not yet been recorded in the United States (exclusive of Alaska). It almost certainly occurs in the norther tier of counties in Minnesota. The presence of *disa* at Aweme, Manitoba suggests that it might also occur in the Turtle Mountain area of North Dakota and there is also a good possibility

that it will be found in the Rockies of western Montana. The map (figure 1) shows the known localities and suggested range of *Erebia disa* in the central area. The Alberta localities are from Bowman (1951); the data for the other localities follows:

MANITOBA: Gillam (G. S. Brooks, 1942 and F. H. Chermock, 1967); Thompson (F. H. Chermock, 1967); The Pas, 1 July 1968, J. H. Masters and P. J. Conway; Harte Mountain, Porcupine Prov. Forest, 2 July 1968, J. H. Masters and P. J. Conway; Favel River, Duck Mtn. Forest Reserve, 3 July 1968, J. H. Masters and P. J. Conway; Blue Lakes, Duck Mtn. Prov. Park, 5 July 1968, J. H. Masters and P. J. Conway; Lake Jane, Riding Mtn. National Park, 25 June 1967, J. H. Masters; Aweme, N. Criddle (Brooks, 1942); Sandilands Provincial Forest (2 locations), June 1967, C. S. Quelch and John Polusny; Whiteshell Provincial Park, 29 June 1968, J. H. Masters.

ONTARIO: Reed Narrows, 29 June 1968, J. H. Masters; Longbow Corners, 29 June 1968, J. H. Masters and P. J. Conway; Hymers (Riotte, 1962); Favourable Lake (Riotte, 1959); Geraldton (Riotte, 1959); Nakina (Riotte, 1959); Ogoki Post (Riotte, 1959); Smoky Falls (Riotte, 1959).

SASKATCHEWAN: Harlan, June, R. J. Fitch (Masters, 1968); North shore of of North Saskatchewan River, 20 miles north of Lloydminster, June, R. J. Fitch (Masters, 1968); 5 miles east of junction of highways 165 and 106, 10 June 1968, J. S. Nordin.

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METHODS FOR STUDYING THE CHROMOSOMES OF LEPIDOPTERA

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CHROMOSOME INFORMATION has been published on over two hundred butterfly species in the Palearctic region (de Lesse, 1960, and included references). A smattering of chromosome counts has been published on African species of Rhopalocera (de Lesse and Condamin, 1965, 1966), and an initial survey of 105 Nearctic and northern Neotropical species has been given by Maeki and Remington (1959, 1960a, 1960b, 1960c). Some Australian species have been studied cytologically (Emmel & McFarland, unpublished). Recently, de Lesse (1967) published a list of the chromosome numbers of 284 Neotropical Rhopalocera, all from South America; these include 14 species already counted by Maeki and Remington from northern Mexico. These references are the only major publications to date on butterfly chromosomes. Yet with the exception of Drosophilidae no other large group of animals approaches the degree of cytotaxonomic knowledge (over 700 species) we now have of the Rhopalocera (Maeki and Remington, 1960c). The karyotypes of the moths are almost totally unknown.

In the course of extensive investigation of the karyotypes of Neotropical and Nearctic butterfly species, the author has developed a simplified set of techniques for obtaining and studying the chromosomes of Lepidoptera. The purpose of the present paper is to outline these methods.

COLLECTION AND PRESERVATION OF TESTES

Chromosomes are most easily studied in dividing cells in the testes of male butterflies. Meiosis usually continues there for some time after eclosion (up to several months in *Heliconius* species), the haploid number is easier to observe than the diploid complement of mitotic somatic cells, and meiosis in the eggs of a female only occurs singly during the short interval of sperm combination with each egg (see also Maeki and Remington, 1959).

In almost all butterflies, the two testes are fused laterally and located at the *top* of the abdomen, beneath the junction of the third and fourth abdominal segments counting forward from the genitalia (the easiest way to count in the field). In the large sulfur genus *Phoebis* and certain other Neotropical butterflies, the testes are placed in the top of the clasping apparatus (terminal abdominal segment).

Location: The roundish or oblong testes are always in the *center* and have two long tubes attached to their joined base.

Color: They are usually *rose* or *red*, but may be *greenish*, *black*, *yellow*, or even *clear* in many lycaenids, satyrids, and certain Papilios.

Size: This varies greatly, depending on age (decreasing size in older individuals) and the species. *Heliconius* and danaiids have testes up to 2 mm in diameter. In some satyrids and lycaenids (blues), they may be only 0.1-0.2 mm in diameter.

Directions for Removal of Testes:

To remove the testes, hold the male butterfly in the left hand with its wings above the thorax; shove the abdomen at an angle downwards with a free finger. With fine watchmaker's forceps (No. 5 size is best) in the right hand, tear open a slit in the top of the abdomen at the junction of the third and fourth segments back from the claspers (Fig. 1). The distinctively-colored testes should pop into view immediately; the other abdominal contents are yellowish, white or translucent.

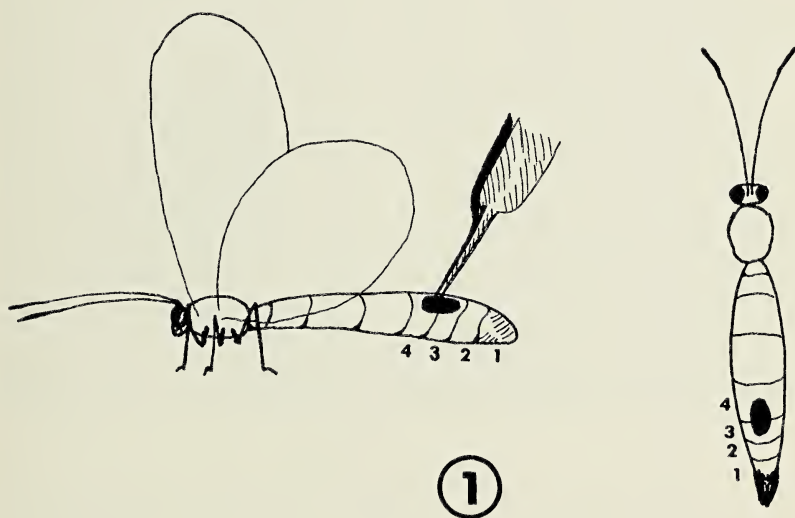
Pull off the testes and place into a screw-cap vial (one- or two-dram size are satisfactory) containing a 3:1 mixture by volume of absolute ethyl alcohol and glacial acetic acid (freshly mixed or not more than a few hours old). Push the abdominal contents back in the male's abdomen, close the slit, and store the specimen in an envelope for future reference. Put a label with a pencil-written code number in the vial with the testes; put the same number in ink on the glassine envelope containing that male specimen; and enter the same number and collection data in a permanent notebook. The wing condition or apparent age of the male can be noted, also. Use a different vial for the testes of each individual butterfly.

The testes can be stored in the original vials until chromosome squashes are made; it is not necessary to transfer them to alcohol for storage. The vials should be refrigerated and if possible

stored at freezing temperatures at the earliest opportunity. The testes will give satisfactory chromosome preparations even after two years of frozen storage, though faster processing is recommended.

Because some individuals in a population may not be undergoing active spermatogenesis at the same time as others, it is advisable to collect 5-10 testes for each species (or more if there is known to be a variable number of chromosomes in populations of that species).

The collection of testes from live males does not have to be done immediately upon netting of the specimens. Males can be left alive (unpinched) in glassine envelopes all day as long as they do not get overheated, and the testes can be removed in the evening as each male is killed.



SQUASH TECHNIQUE FOR CHROMOSOME STUDIES

The following squash technique is the simplest and fastest one to use to obtain good preparations of chromosomes which then may be photographed and drawn via camera lucida for permanent record. This procedure does not produce permanent slides, though these squash preparations may be sealed with clear nail polish and held at freezing temperatures for several years if desired. However, slides may be made permanent by dehydrating the preparations in a series of alcohol concentrations (Guthrie, Dollinger, & Stetson, 1965).

1. After removing testes from fixative in the vial or from a freshly-killed male, place on a clean slide in a drop of Lacto Orcein Stain (see Appendix I).
2. Macerate the testes with watchmaker's forceps. Allow to

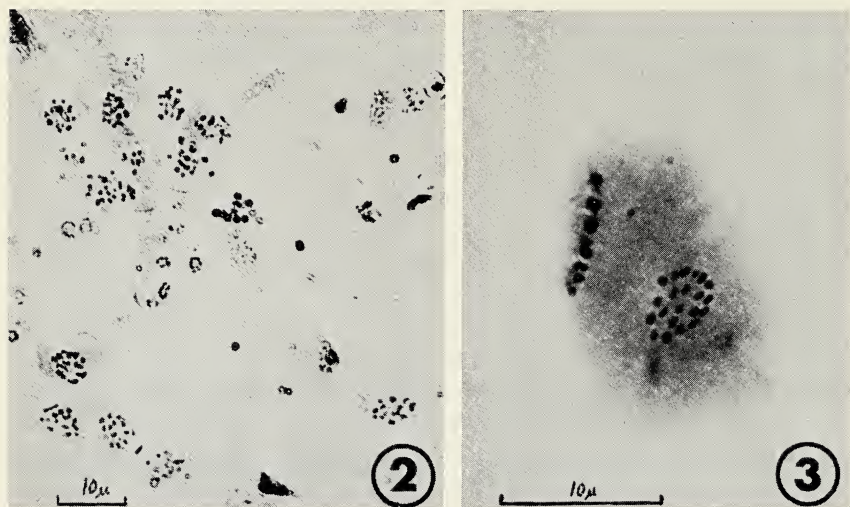


Fig. 2. General field of dividing testicular cells at 400x microscope magnification. *Eurema* sp. (Pieridae), San Vito de Java, Puntarenas Province, Costa Rica ($n=29$). It is relatively rare to obtain cells with all chromosomes in the same plane of focus; only one or two of the sets of chromosomes in this field of view could probably be counted accurately (at higher magnifications).

Fig. 3. Highly magnified haploid set of chromosomes ($n=21$) from a testis cell of a *Heliconius melpomene* male (Nymphalidae: Heliconiinae), Osa Peninsula, Puntarenas Province, Costa Rica. The line of chromosomes at left represents an equatorial view of chromosomes on a metaphase spindle in a neighboring cell. The microscope magnification for this photograph was 1000x.

stand for at least 5 minutes. (A longer exposure to the stain, up to several hours, gives better results. Cover stain drop with a small watch glass to prevent evaporation).

3. Place cover slip over drop of stain. Tap the top of the cover slip to spread out cells.
4. Put a paper towel or filter paper on top of cover slip and squash by thumb pressure over cover slip. (Or, the slide may be inverted, placed on a sheet of glass with paper toweling above and below, and thumb pressure applied to squash.) A Carver Laboratory Press may be used to insure a uniform, well spread chromosome preparation.
5. Remove excess stain around edges of cover slip with filter paper and examine slide under low power (100x) to locate areas of dividing cells.

Dividing cells may be examined under oil-immersion for counting, description and photography. The author uses a Carl Zeiss Research Microscope STANDARD WL fitted with plan-apochromatic flat-field objectives and automatic camera. An oil-immersion Planapo 100x objective is used for critical observation and photography. Total magnifications of at least 1000x are needed for studying the tiny chromosomes of the Lepidoptera.

Examples of the appearance of areas of dividing testicular cells and of chromosomes at high magnification are given in Figures 2 and 3.

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APPENDIX I

Lacto Orcein Stain

1 gm	Orcein
40 cc	Glacial Acetic Acid
10 cc	Lactic Acid (undiluted)
50 cc	Water (distilled)

Bring to a boil, let mixture stand in flask overnight, then filter with Whatman No. 1 filter paper to remove crystals. Store stain in small nose-dropper bottles.

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NOTE ON VITAL STAINING OF *ACTIAS LUNA* SILK

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VITAL STAINING RESULTS with *Pieris rapae* (Linnaeus) and *Colias* species have been reported (Kolyer, 1965 and 1966). In *P. rapae*, the dye neutral red imparted a red tint to all stages, and Sudan black B gave bluish larvae, greenish-black pupae, and blue internal color in adults. Silkworms fed neutral red spin "bright red" cocoons (Edwards, 1921).

In the present work, the dyes fed to *Actias luna* (Linnaeus) larvae (5th instar) were neutral red, Colour Index No. 50040, total dye content 88%, and Sudan black B, Colour Index No. 26150, both obtained from Allied Chemical Corp., New York City. These were ground and blended with P-12 Davenite mica (325 mesh; Hayden Mica Co., Wilmington, Mass.) at 3 parts dye per 97 parts mica, and the blend was rubbed on the underside of hickory leaves at about 18 mg. blend/in.² surface. Incidentally, with stems in water the leaves kept well below 80°F at about 50% rel. humidity but wilted rapidly at 85-90°F.

Neutral red showed toxicity and caused pronounced inhibition of growth, as noted for the butterfly species. While no mortality occurred among control larvae, of 16 larvae fed the dye for 2-8 days (followed by feeding undyed leaves if larvae hadn't died) only 2 survived to produce cocoons; these were fed dye for 2 days, at which point one began spinning while the other began a day after being transferred to undyed leaves. Success seemed to depend on feeding dye only long enough to saturate the body with the color (2 days, or even as little as 12 hours with voracious feeding) and on choosing larvae almost ready to pupate.

Four larvae were fed Sudan black B for 7 days and then transferred to undyed leaves. Only one survived and spun a cocoon. In this case, desorption of dye from the body was indicated; feeding on undyed leaves caused gradual loss of the deeper green shade given by the dye. Similar reversibility of neutral red has been noted for the wild silkworm *Attacus orizaba* (Edwards, 1921) as well as in the cited work with butterflies. The cocoon was uncolored like that of a control.

The two strongly-pink or rose colored cocoons from the neutral red experiment were opened to disclose dead larvae. After discarding the latter and picking all leaf fragments from the silk, the cocoons weighed 70 and 79 mg. Each cocoon was assayed for neutral red by triturating a sample (37-39 mg.) with 6 ml. of concentrated (37-38%) aqueous HCl, filtering, and measuring optical density at 725 millimicrons with a Bausch and Lomb Spectronic 20 Colorimeter. A calibration curve was constructed using known concentrations of dye in the HCl solution. The result was $1.3 \pm 0.1\%$ neutral red (as "total dye") in the cocoons. Experiments with *Attacus orizaba* (Edwards, 1921) have shown that the neutral red in the cocoon indeed is transferred to the sericin through the insect's body rather than being picked up externally during spinning.

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PRESENT AND ICE AGE LIFE ZONES AND DISTRIBUTIONS

WILLIAM HOVANITZ

IN DESCRIBING THE DISTRIBUTIONAL RANGES of any insect, it is very desirable that some means of rapid correlation with a climatic zone (or vegetational zone) be available. Many years ago, Merriam (1898) found a scheme of "life-zones" useful for the purpose of describing the distribution of North American mammals; such zones were heavily relied on by other vertebrate zoologists as an aid toward the ecological description of distribution patterns (see Grinnell and Storer, 1924 and Hall and Grinnell, 1919).

In addition to existing life zones, some idea of the distribution of the zones in the immediate geological past is desirable. L. S. Dillon (1956) has attempted to show the relationship between the life zones of the present and of the ice age. The reader should refer to his paper for an excellent discussion of the subject. Nevertheless, since that paper is not readily available to many readers of this *Journal*, two significant maps from that paper are here redrawn and reproduced in color. The first is a simplified map of Merriam's Life Zones of the present and the second is a map showing the presumed or hypothetical location of the same life zones during the Wisconsin ice age.

Of prime importance to formulation of conclusions on the possible reasons for some idiosyncrasies in present day distributions, one major fact emerges. Continuity of distribution between Alaska and the more southerly parts of North America which existed before and now exist after the ice ages were completely broken for a long period of time. For example, if one took a group of *Colias* such as *Vaccinium* feeders which are nearly circumpolar, it is apparent that these could extend without much discontinuity from Europe across Asia into Alaska and across northern North America. The ice barrier of the Pleistocene, however, effectively isolate the Alaska end of the Asian distribution from the more southerly parts of the North American distribution and the possibility of local races or species developing

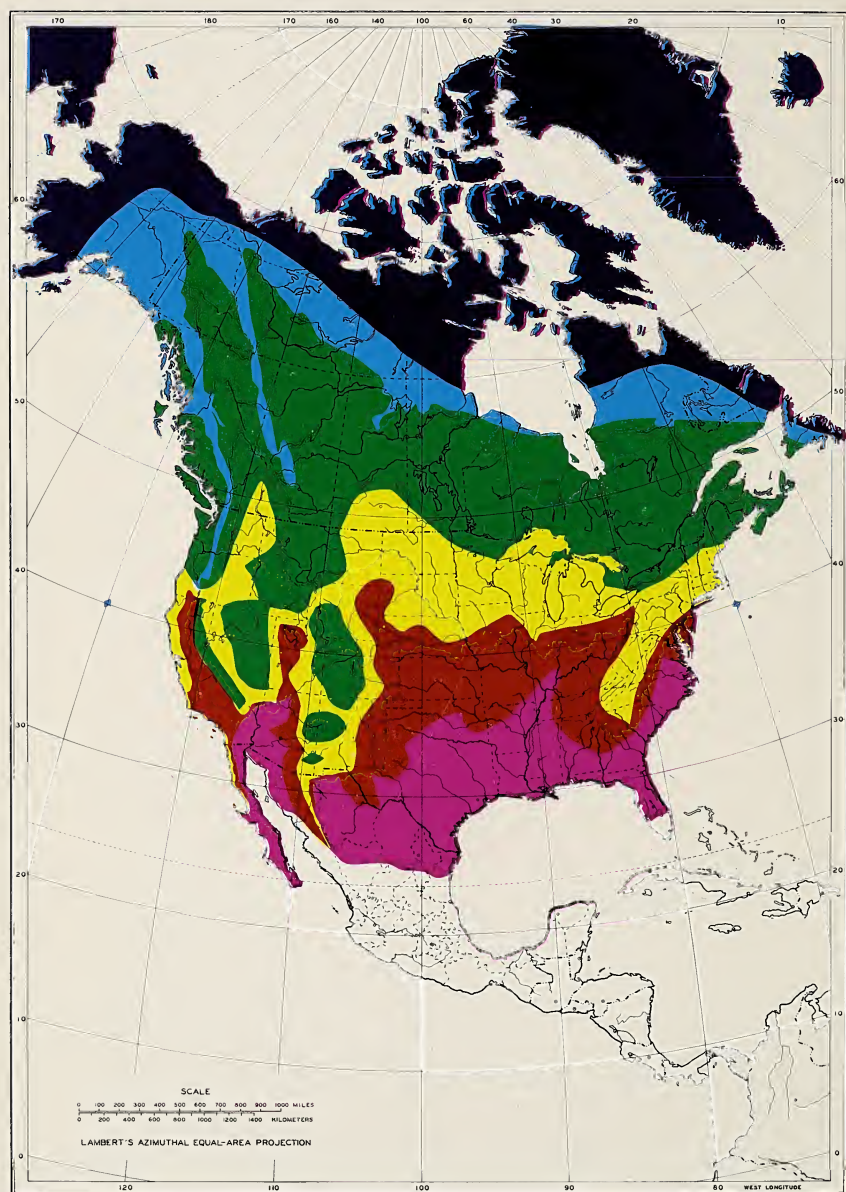


FIG. 1 Present day life zones (simplified from Merriam and Dillon). Purple: Arctic-alpine (tundra); blue: Hudsonian; green: Canadian; yellow: Transition; red-orange: Upper Austral (Sonoran); red-magenta: Lower Austral (Sonoran). Ice not shown in Greenland and adjacent islands.

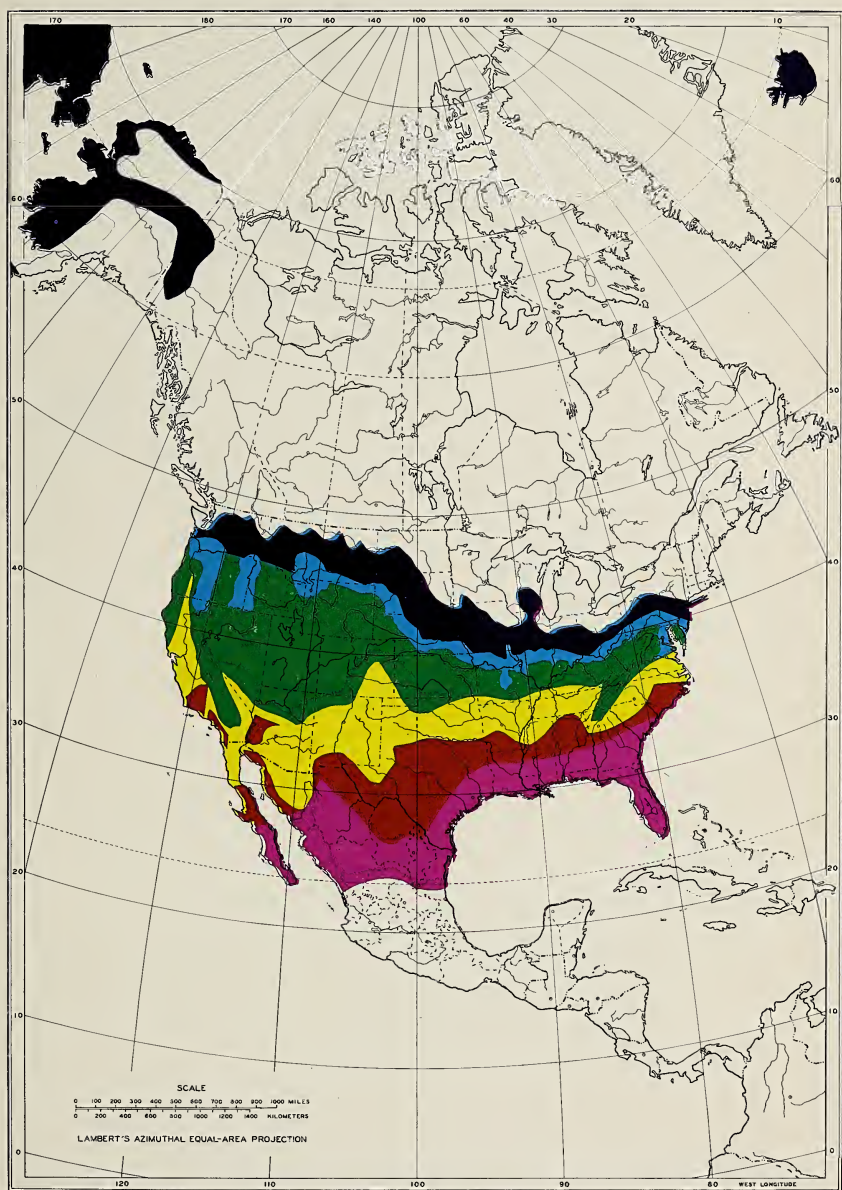


FIG. 2. Hypothetical life zones of the Wisconsin ice age. Same legend as Fig. 1 except white in north designates arctic glaciation. Both these figures have been redrawn from Figures 10 and 11 of Dillon (1956) and reproduced in color by permission of Lawrence S. Dillon and *Science*, published by the American Association for the Advancement of Science, Washington, D.C.

would be strong. *Colias paleano* (The Eur-Asian *Vaccinium* feeder) would remain in that sector but new forms would develop through genetic isolation and habitat selection south-east of the ice. For example, *Colias interior* might have developed spanning the North American continent, or *Colias minisni* in the southern Canadian Rockies, or *Colias behri* in the Sierra Nevada, or *Colias pedidne* in Labrador and possibly *Colias scudderi* in the southern Canadian Rockies. Movement northward of *Colias interior* and southward of *Colias palaeno* after the retreat of the ice would create a zone of hybridization if they retained the same ecological niches, and were still interfertile. But such was not the case and from the mouth of the MacKenzie River to Manitoba, they overlap with no known mixing. Two other species (*Colias hecla* and *C. nastes*) however have been confused by the new habitats following retreat of the glaciers and have partly blended together with the formation of a partial new species (*Colias boothi*) (Hovanitz 1950, 1951 and 1963).

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TRIALS OF SEVERAL DENSITY ESTIMATORS ON A BUTTERFLY POPULATION

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INTRODUCTION

THE DENSITY OF AN ANIMAL POPULATION is notoriously difficult to estimate, and new methods are consequently being developed continually. Since some newer procedures have been tried little in the field, our objective was to compare several of them to several older ones.

Some of the extensive literature on population estimation has been reviewed by Hanson (1967), Southwood (1966), and Ricker (1958), making further discussion of the theory not now warranted. The book by Southwood emphasizes entomological applications, and especially how to obtain reliable data. It bears repeating that workers have found it considerably easier to develop the mathematical bases of the estimating techniques than they have to solve the biological and economic problems of getting unbiased data in adequate amounts for use in the estimators.

To compare the estimating procedures, we required to study: (1) a natural population, (2) one that was fairly dense, (3) a relatively isolated population, to reduce egress of marked animals, (4) yet one comprising a highly mobile species, and finally, (5) a population that could be found close at hand and approached and captured with a minimum of problems. For these purposes, the common alfalfa butterfly (*Colias eurytheme*) turned out to be very good. The habitat and behavior of the alfalfa butterfly, among other matters, were discussed by Hovanitz (1948).

A suitable population of the butterflies was found in a field of alfalfa (*Medicago sativa*) located on an experimental farm of California State College at Pomona. The field contained 14.2 acres, was rectangular in shape, and was surrounded by grass,

fallow land, and an orange grove. It appeared to be well isolated from other areas providing habitat for *Colias eurytheme*. The alfalfa was somewhat thinly planted and averaged about 12-14 inches tall. The field data were collected on three consecutive days, August 13 through 15, 1964. (Further work was attempted in another alfalfa field in August of 1966 but inadequate isolation of the population precluded any reliance on marking methods.)

METHODS OF GETTING DATA

Throughout the field, two or more workers moved about at random, netting the butterflies that came within reach. Upon capture, each butterfly was marked with a spot of nail polish on the ventral, distal surface of the wing; the butterfly was held for a few moments to allow the paint to dry and then was released, in the manner to be described in a forthcoming paper by Hovanitz. By using several dots, it was easily possible to show how many times a given individual butterfly had been captured. Marking was not continued beyond the second day.

Concurrently with this effort, in a second "experiment," two other workers attempted to make total counts on sample plots in the Cal Poly field. Before our work began, the alfalfa field had been divided lengthwise into 10 strips, each about 93 feet wide, by low dikes erected to keep irrigation water in place. As the observers moved lengthwise along each resulting strip, they walked 20 long steps (about 60 feet) and counted all butterflies within the resulting "plots," then stopped and recorded the insects seen, and continued to repeat this process. The size of the plots (60 x 93 feet) was determined partly by the fact that the observers concluded not to count any butterflies that were more than 60 feet beyond them.

In another experiment, a series of cursory, incomplete counts was made in this alfalfa field by one observer. In this case the observer walked rapidly back and forth across the field from one side to the other. The beginning point and ending point of each walk were guided on a stake previously set at the middle of each side. When he crossed the field, the observer's eyes were fixed straight ahead on the stake located at the far side, but all *Colias* that could be seen within the arc encompassed by the observer's vision as he looked straight ahead were included in the counts. Since the field was crossed 35 times, 35 superficial samples of butterflies were gathered.

FREQUENCY OF CAPTURE

The repeated capturing, marking, and releasing of the butterflies produced a frequency distribution in which f_1 butterflies were caught x times, f_2 were caught $2x$ times, and so on up through f_i animals taken x_i times for each of the two days on the Cal Poly field, as is shown in Table 1. (The estimated abundances of butterflies according to this and all other methods is shown in Table 2.) The resulting data were used to estimate the frequency of the animals seen zero times, i. e., to estimate the missing class f_0 in the truncated distribution. After the number of unseen animals was estimated, obviously it could be added to the number of those actually seen to give the estimated total number of butterflies in the whole population.

As was discussed in the earlier review (Hanson, 1967), several papers give promising procedures for estimating the total abundance, K , of the population from such frequency of capture data. Among these, the paper by Craig (1953) contained a refined version of a moment model using data obtained by Hovanitz (Method 2 of Craig's paper), which required the data to have an underlying Poisson distribution; this model was tried on the data shown in Table 1. A paper by Edwards and Eberhardt (1967) contained several estimating procedures, among which was the maximum-likelihood model requiring data coming from a geometric distribution.

A further procedure mentioned by Edwards and Eberhardt involved plotting of the capture frequencies on semi-log paper. It is well known that when a regression relationship is curvilinear, it can often be transformed into a linear one by plotting the logarithm of one or both variables (see, for example, Bailey, 1959:94). In the familiar expression for the linear regression line

$$Y = a + b X,$$

Y is the dependent variable; X is the independent variable; a is the height on the Y axis where the line began, and b is the slope of the line. One can plot the number of animals captured once against the number 1, the number captured twice against the number 2, etc. When semilog paper is used and the number of animals is plotted on the logarithmic scale (i.e., on the Y axis) and the number of times that they were captured is plotted on the equal-interval scale (i.e., on the X axis) a straight line may result. If the points (X,Y) result in a straight line, then the transformed statement of the regression equation must have finally ended up with the form (see Steel and Torrie, 1960:334):

$$\log Y = a + bX.$$

TABLE 1

The Number of Times That Butterflies (Colias eurytheme) Were Captured
and Marked in an Alfalfa Field Near Pomona, California

	x	f	xf	x ² f
	(Number of Captures Per Individual)	(Frequency)		
I. ALL SEXES:				
	0	---	---	---
	1	81	81	81
	2	35	70	140
	3	11	33	99
	<u>4</u>	<u>1</u>	<u>4</u>	<u>16</u>
Sum:	---	128	188	336
II. FEMALES ONLY:				
	0	---	---	---
	1	46	46	46
	2	24	48	96
	3	10	30	90
	<u>4</u>	<u>1</u>	<u>4</u>	<u>16</u>
Sum:	---	81	128	248

However, the last equation differs from the expression used by Edwards and Eberhardt (1967:92), which they got from the geometric-distribution model, since their expression had the form

$$\log Y = a + X \log b .$$

Therefore, it seems doubtful that plotting the capture frequencies on semilog paper, and the corresponding number of times each animal was captured on the equal-interval scale, will preserve the meaning of the geometric expression, but statisticians should investigate the matter further. In any case, the plotting of our data on semilog paper gave good estimates, as will be shown later (Figure 1).

Poisson Estimator

The data on captures of *Colias eurytheme* for use in the Poisson estimator shown as Method 2 in Craig, 1953) are given in Table 1, and the estimated number obtained by all methods are summarized in Table 3. Based on the data for all sexes, the result for Method 2 gave

$$\hat{K} = 188^2 / (336 - 188) = 239.$$

When the error is expressed as a decimal fraction of the estimated mean according to Craig's formula the result at the 95% confidence level is:

$$\text{Standard Error} = \sigma_{n/n}^2 = 2 (239) / 188^2 = .1162.$$

Therefore, the confidence limits became (Table 3)

$$185 < 239 < 293 .$$

When only the data for females were used, the estimated number of females was 137 and its 95% confidence limits were 102 to 172. Because the sex ratio among butterflies seems usually to be approximately unity, these numbers can be doubled to give $K = 274$ and a confidence interval extending from 204 to 344 (Table 3).

As work progressed, some marked butterflies moved out of the field, and the population started declining. We suspected that the insects moving out were, as usual, mainly males, which made the results based on females better than that based on both sexes combined. Although the real number of butterflies inhabiting the field when work began was obviously unknown, the results show that it was approximately 275, and the 95% confidence limits extended from 200 to 350.

Evidently the data did come from a Poisson distribution or from one that approximated it tolerably well. The procedure required that \underline{p} not change much from trial to trial, and evidently

TABLE 2

The Number of Times That Free-Ranging Butterflies (Colias eurytheme)
Were Observed on Sample Plots in an Alfalfa Field Near Pomona, California

x (Number of <u>Colias</u> Seen Per Plot)	f (Frequency of Plots)	fx (Total <u>Colias</u>)	fx ²
0	60	0	0
1	27	27	27
2	16	32	64
3	4	12	36
4	4	16	64
Sum: ---	111	87	191

Variance = $s^2 = 1.116$

Mean = $\bar{x} = .784$

this condition was met. The labor of capturing the butterflies during the hot weather was considerable, yet was small compared to that required to catch and mark animals such as fishes, birds, and mammals with nets, baited traps, or comparable means.

In summary, the frequency-of-capture method using the Poisson model gave good results. Movement of marked butterflies off the study area was a problem, just as it is for mark-and-recapture models or removal models (see Ricker, 1958:86 for further discussion), making it necessary to work quickly and to stop as soon as a few of the animals have been captured as many as four times.

Geometric Estimator

When the same basic data (Table 1) were used in the equation of Edwards and Eberhardt (1967), the results were

$$K = \frac{128}{1 - (128 - 188)} = 401$$

Confidence limits were not calculated since no procedure for this was given by Edwards and Eberhardt.

The estimate of 401 butterflies obtained from the geometric model was well above what we believed to be approximately the correct upper bound of 350. Why this model did not give as good an estimate as the Poisson was not clear, but possibly it was because the geometric model is more suitable for contagious (clumped) spatial distributions. However, these butterflies flew about in an apparently random manner, and gave no evidence of significant aggregation.

Regression Estimator

When the frequencies-of-capture were plotted on semi-log paper, the resulting points fell remarkably close to a straight line (Figure 1). For both sexes combined, the fit was very good except for the class of four captures per individual, where the sample size was, of course, very small. When this point was ignored, the plotted line indicated that the zero class of frequencies was about 162, and that the total population was thus about 290 (Table 3). For females only, the fit of the line was even better (Figure 1), and it indicated that about 234 animals were not captured, making the total population about 315 (Table 2). Both estimates are near what was believed to be the true number, 275.

Since the method showed promise and could be applied quickly, it should be tested considerably more. Getting the

TABLE 3

Summary of Estimates of the Number of Butterflies (*Colias eurytheme*)
Occurring in an Alfalfa Field Near Pomona, California

Method	k	95 Confidence Limits	
I. FREQUENCY OF CAPTURE			
1. Poisson, Both Sexes, 1st Day.	239	185	293
2. Same as Preceding, Except: 2nd Day	46	Not Calculated	
3. Same as Preceding, Except: Based on Females Only, 1st Day; Results Were Doubled (to Include Males).	274	204	44
4. Frequency of Capture - Geometric Model, Both Sexes, 1st Day.	401	No Procedure Available	
5. Same as Preceding, Except: Based on Females Only; Results Were Doubled (to Include Males).	442	No Procedure Available	
6. Frequency of Capture - Regression Method, Both Sexes, 1st Day.	290	Not Calculated	
7. Same as Preceding, Except: Based on Females Only, 1st Day; Results Were Doubled (to Include Males).	315	Not Calculated	
II. TOTAL COUNTS ON SAMPLE PLOTS			
1. 1st Day	87	65	109
2. Same as Preceding, Except: 2nd Day.	102	Not Calculated	
III. RELATION OF VARIANCE TO MEAN			
1. Cursory Counts, 111 Plots Occurring in 8 Rows, 1st Day.	0	Not Calculated	
2. Same as Preceding, Except: 2nd Day.	0	Not Calculated	
3. Same as Preceding, Except: Based on Sum of Each of 8 Rows; 1st Day.	664	21	
4. Same as Preceding, Except: Data for Both Days Combined (n = 16 Rows).	0	Not Calculated	
5. Same as Preceding, Except: Whole Field Subject to Scanning, 3rd Day.	0	Not Calculated	
IV. MARK-RATIO MODEL			
1. The Dahl, or Petersen Method, Data from Both Days	307	210	610
V. REMOVAL METHOD			
1. Data from 1st Day.	187	0	402

data for plotting the regression line is obviously subject to all of the problems affecting other methods based on marked animals (see Ricker, 1958:86-100; Hanson, 1967).

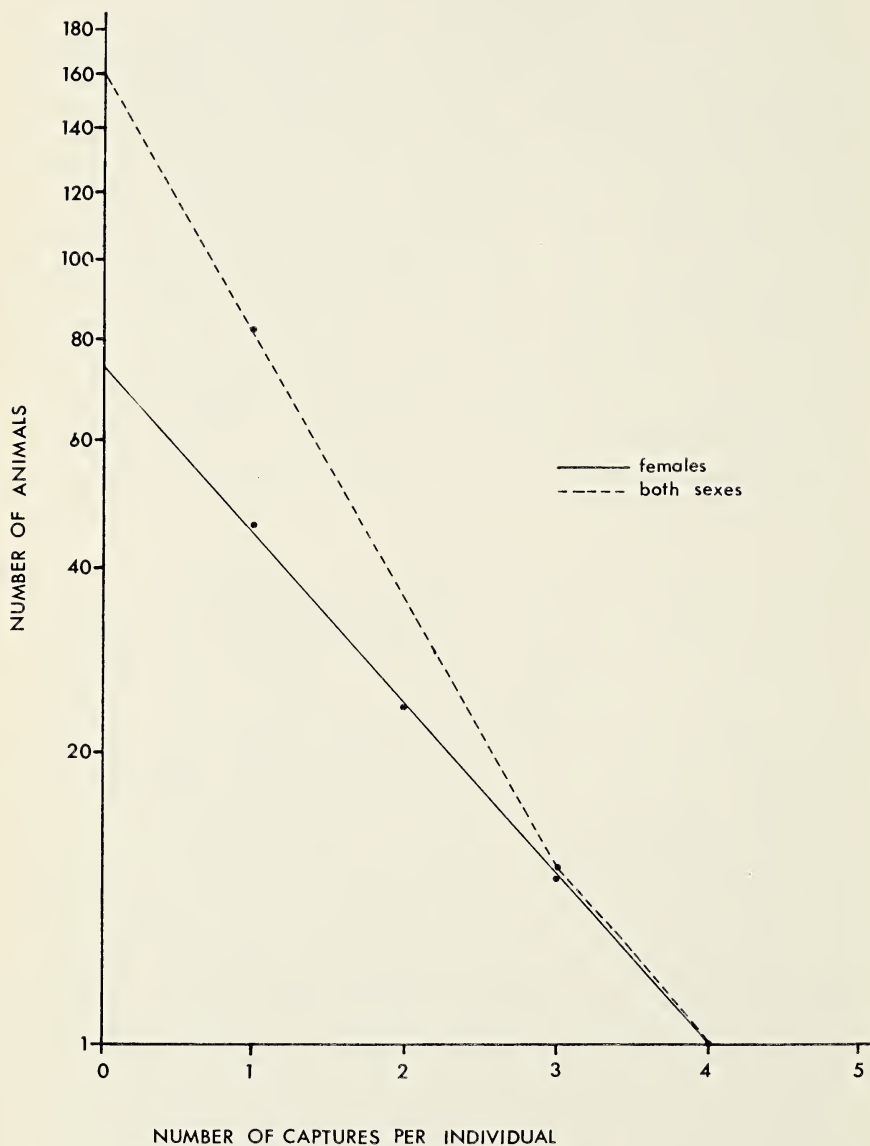
TOTAL COUNTS ON SAMPLE PLOTS

On the first day 87 animals were counted and on the second day two counts yielded, respectively, 87 animals (Table 3) and 102 animals. These figures were undoubtedly much too low, mainly because resting butterflies were tending to fly off the plots before the observers could determine whether the butterflies were within a plot's boundaries. Also, the relatively rapid and erratic flight paths of moving butterflies made it difficult to tell when they were above a given plot and the observers erred on the conservative side. Since the confidence limits for the first day's estimate were rather narrow (Table 3), the bias appeared to be rather consistent. The method of total counts could be made more useful by (a) marking off the boundaries in a more elaborate, easily-recognized way than was done here and (b) by enlarging the plots; but we believe that, for highly mobile animals such as *Colias eurytheme*, the plotless, frequency-of-capture methods are superior when ingress and egress are not important problems.

RELATION OF VARIANCE TO MEAN

This method is described (Hanson and Chapman, in press; Hanson, 1967) as a method for rapidly estimating the number of groups of free-ranging animals from cursory, incomplete counts. None of the animals need be marked or removed, and total counts of any component are not required; but, on the other hand, the model requires (in addition to the usual random sampling) that the data come from a binomial distribution. Although individual animals usually tend to be clumped spatially, the groups themselves should be distributed more at random, leading to a binomial distribution of groups. Therefore, the model deals only with groups. After the worker estimates the total number of groups, he would of course multiply by the average group size to get total population. Since the alfalfa butterflies were here essentially solitary, except for some very brief liaisons between copulating individuals, it turned out that group size was usually 1. However, as is indicated by the estimates shown in Table 3, the proper data could not be obtained.

The data on the counts of individuals seen per plot and the resulting variance and mean per plot are shown in Table 2. When the data were substituted in the proper formula the results gave



$$K = \frac{.784^2}{.784 - 1.116} = 0$$

Since the variance exceeded the mean, this caused a negative estimate, interpreted biologically as a population of size zero (Table 3).

When the preceding samples of Table 2 were combined within each of the 8 transects to smooth out random error, 8 samples of butterflies were obtained: 8, 17, 11, 7, 11, 12, 13, 8. For this series, the mean was 10.875 and the variance was 10.697, leading to the following estimate of the total population (Table 3):

$$\hat{K} = 10.875^2 / (10.875 - 10.697) = \text{ca. } 664.$$

The 90% confidence limits were obtained from Dr. Chapman's equations (Hanson and Chapman, in press)

$$1 - \frac{(7)(10.697)}{(10.875)(2.17)} < p < 1 - \frac{(7)(10.697)}{(10.875)(14.1)}$$

where 2.17 and 14.1 are the upper and lower values of Chi-square, for 7 d.f. and .95 and .5 probability, respectively, read off from a table such as that of Fisher and Yates (1957:45). After the indicated arithmetic is performed, it resulted in

$$1 - 3.17 < p < 1 - .488 .$$

Since a negative value of p in this double inequality (on the left alone) is biologically impossible, the lower bound could not be less than 0, and the confidence interval for the probability of seeing a given animal became

$$0 < p < .512 .$$

The confidence limits for K finally became $10.875 / .512 = 21.24$; and $10.875 / 0$, which can be taken as infinity.

All other attempts to estimate K from the relation of variance to the mean failed because the variance was too high. Evidently (a) the true population density varied greatly from one plot to the other or (b) the animals were aggregated into larger groupings that were not recognized as such, or (c) the activities of the observer introduced considerable extraneous variation. Most likely each problem occurred to a degree.

First, the outside transect on each side of the field appeared to continually have fewer butterflies than did the inner transects; why the butterflies tended to use the outside parts of the field less, was not clear, but superficially the alfalfa appeared thinner there.

Second, at times the butterflies were momentarily aggregated a female, but these groups were treated as chance events and the

Colias in them were recorded as individuals (i.e., several "groups" containing one animal each).

Third, the principal cause of the excessive variation seemed to be the lack of an objective method for determining the boundaries of the area scanned and whether or not observed butterflies were within those boundaries during the rapid, cursory counts. Since the estimator based on relations of the mean to the variance would provide an easy and rapid way of estimating density if the proper data can be obtained, it is important to find an objective way to make the counts.

MARK-RATIO MODEL

The well-known mark-and-recapture method, apparently first used on animals by Dahl (1917), and reviewed extensively by Ricker (1958), Southwood (1966), and Chapman (1954), was tried here; for data we had 128 different butterflies caught the first day and 24 caught the second day, of which 10 had been marked at least once. Therefore,

$$\hat{K} = \frac{(128)(24)}{10} = 307,$$

with limits (210, 610) (Table 3).

The small size of the sample caught on the second day, small in spite of considerable effort, indicated that much of this *Colias* population had left the field. Egress would cause no problem so long as the ratio of marked to unmarked animals did not change. Since there seemed to be no evidence that marked animals were leaving at a faster rate than the others, the estimate of 307 was reasonably close to the true population size. The confidence limits were somewhat wide, mainly because of the small sample in loose groups, perhaps due to attraction of several males to size collected on the second day.

REMOVAL METHOD

The removal method of population estimation was apparently begun by Hjort and Ottestad (1933) and has since been reviewed by several persons, including particularly Zippin (1956). In the present work it was expected that the count for the first day could be compared to that for the second day although no animals nor plots were removed. It was planned that any animal caught on the second day that bore a mark from the first day would be treated mathematically as dead. However, the decline in population size during the two days negated one of the main requirements for use of the removal models. As a result, another approach was tried.

For both sexes combined, 81 butterflies were caught once on the first day, and 35 were caught twice on that day (Table 1). Now let it be imagined that two independent samples had been taken on that day, each involving equal effort and the other standard assumptions of the removal method, and that in the first sample 81 animals were caught. If efforts, etc., were constant, then 81 should have been caught in the second (hypothetical) sample, of which 35 would have been carrying earlier marks. The 35 marked ones (Table 1) found in the second imaginary sample may be subtracted from the 81 assumed caught, leaving 46 as the size of the unmarked portion in the second sample. This manipulation provides the raw data for use in the estimating equation:

$$K = \frac{81^2}{81 - 46} = 187 .$$

Where c_1 and c_2 are the number of animals caught and removed on the first and second surveys, respectively, then the standard error of the estimate is (Zippin, 1956)

$$\frac{c_1^2 c_2^2 (c_1 + c_2)}{(c_1 - c_2)^4} = \frac{(6561) (2116) (127)}{1,500,625} = 108 .$$

Therefore, the upper and lower limits, at the 95% confidence level, were (0, 402) (Table 3).

The estimate of the total population size, 187, seemed too small, although the confidence limits included the most reasonable values, 275 to 300. The difficulty seemed to be that more unmarked animals should have appeared in the second sample, requiring that the number marked for the second time should have been smaller. Therefore, the possibility was present that once a butterfly was marked, it was more prone to be caught again, but if this were so, the estimate based on the Dahl mark-ratio method should have been smaller. The question was not definitely answered but "prone to capture" should not have caused much trouble.

DISCUSSION AND SUMMARY

How satisfactory any estimator of density does perform depends in part on each person's concept of what is "satisfactory." According to our experience, most zoologists expect results too close to the real population mean and often seem to think that an error much over 10-20% is excessive. Yet considering the many possible sources of error even in stationary populations such as

plants, it is a wonder that a highly mobile animal group can have its density estimated within one order of magnitude. Certainly it appears that estimates on highly mobile animals should be considered reasonably good if they are within 50% of the true population size, although attempts should of course continue to be made to find better techniques.

Viewed in this light, several estimates obtained in the present study were fairly close to what seemed reasonable, that is about 275 to 300; frequency-of-capture models, based on either the Poisson distribution or on a regression line, and the mark-ratio model gave estimates near that value. Methods based on finding plot boundaries, such as the mean-variance model or total counts, were not as satisfactory, although they might become so when the plots are larger and better marked. At least 128 different butterflies were caught and marked, and the latter sets a known minimum limit for the population. The upper limits were either about 344 (frequency-of-capture, Poisson), 402 (removal method), or 610 (mark-ratio method) (Table 3). Which of these is better cannot be dogmatically stated, since the correct answer rests partly on a matter of intuition, and confidence level associated with the value selected. In our opinion, the true upper limit of the population estimate should have been not more than about 400, i.e., 25% above the upper end of the most probable estimate of K .

The only adequate method for deciding the proper size of K and its confidence limits is to repeat the experiment a number of times, within a fairly short interval of time; using a variety of models, and particularly obtaining the basic data by a variety of field methods. Unfortunately, if such intensive efforts had been made here they would have driven even more of the butterflies from the place of study, and excessive egress was already the principal difficulty in the present work. Therefore, continued research should be done to find additional methods for estimating density, particularly ones that disturb the population a minimum. The model recently proposed by Hanson (1968) might be helpful in this regard. In a nutshell, the best suggestion for lepidopterists, and zoologists in general, seems to be that they should use several good methods on each population studied and be prepared to accept errors up to 50% of the estimates made.

ACKNOWLEDGMENTS

Wish to thank the following persons: Robert T. M'Closkey, Eric Hovanitz and Roderick Hanson for help with the field; Professor Paavo Voipio, in whose Institute of Zoology of the University of Turku, Finland, the data were analyzed and most of the paper was written; and Miss Linda March who assisted in typing the manuscript.

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HABITAT: ARGYNNIS CALLIPPE LAURINA

The unsilvered form of this complex which includes *callippe*, *comstocki*, *macaria*, *laurina*, *coronis*, *rupestris* and others is found along the lower elevations of the western side of the Sierra Nevada mountain range in California. Occasional specimens of wholly or partially silvered are to be found throughout the range of the race but they are most common toward the south where populations gradually increase in the percentage of silvering until the populations may be called *macaria* in the Kern basin. Silvering picks up again at the north end of the range.

At this location, the primary local vegetation is the Digger Pine and oak woods. Adults fly after the grass is dry, late June and early July. The photograph was taken a few miles southeast of Mariposa, Mariposa Co., California, early July, 1969.

William Hovanitz

1160 W. Orange Grove Ave., Arcadia, California, U.S.A.

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ON MEXICAN SATYRIDAE,
WITH DESCRIPTION OF A NEW SPECIES

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THE CARNEGIE MUSEUM-CATHOLIC UNIVERSITY OF AMERICA expedition to eastern Mexico in January, 1966, collected relatively few Satyridae, mostly of rather common species. Two specimens were of special note, and these are recorded here.

A single female of *Dioriste tauropolis* (Westwood) was collected on 9 January 0-3 miles northwest of Gomez Farias, Tamaulipas, between 280 and 700 m. elevation in the tropical evergreen forest. This specimen and another taken by Mr. L. I. Gilbert (personal communication) apparently represent the furthest north records for *tauropolis*. Godman and Salvin (1879-1901: 108) report it from Cordova and Jalapa, Veracruz, while Hoffmann (1940: 670) lists this species from only Veracruz, Tabasco, Chiapas and Oaxaca. The present specimen (L. D. Miller specimen no. 1966-373) was collected flying in the sunlight along a woodland road.

Members of the genus *Cyllopsis* infrequently are collected in series, so it was a pleasant surprise to take a series of nine specimens in a semi-montane situation east of Ciudad Victoria, Tamaulipas. When the material was prepared eight of the specimens were of the relatively common *C. gemma freemani* (Stalings and Turner), but the ninth was totally unlike any *Cyllopsis* I have seen. My first impression was that the specimen was a singular aberration, but its genitalia are totally unlike those of *freemani*, and this specimen apparently represents a new species.



Figs. 1-2. *Cyllopsis dospassosi*, new species, Holotype ♂. Fig. 1, upper surface. Fig. 2, under surface. About 3.5 times natural size.

Cyllopsis dospassosi, new species

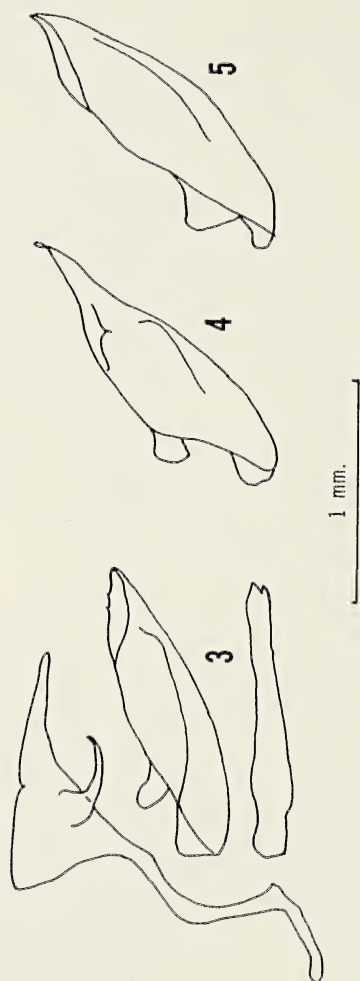
Figs. 1, 2 (Holotype ♂), 3 (genitalia of Holotype ♂)

Male: — Head, thorax and abdomen dark brown densely clothed with dull brown hairs above and tan ones below. Palpi dark brown densely clothed with dark brown hairs above and tan ones below. Antennae dark brown dorsad, tan ventrad with the shaft ringed in dark brown. The legs are clothed with dense tan hairs. Forewings above dull grayish-brown shading to darker dull brown marginally and around the apex to about halfway down the costa; otherwise unmarked. There is no androconial patch of mealy scales below the cell, as are shown in the *hilaria* (Godman) group. Hindwings above also dull grayish-brown, darker at the apex, with double blackish-brown marginal spots in spaces M_2 - M_3 and M_3 - Cu_1 , as well as a faint smaller single spot in Cu_1 - Cu_2 , and the bands of the under side showing through faintly. Forewings beneath olive-tan marked with olive-brown as follows: many scrawls in the basal part of the cell, a large patch at the end of the cell, a spotband just outside the cell from the apex to 2A, the spot in 2A being doubled with the proximal member situated directly below the cell spot, and a marginal spotband from cells R_5 - M_1 to Cu_2 -2A. The hindwings below are of the same olive-tan color as the forewings, scrawled basally with olive-brown and with two transverse broken bands of the same color from the costa to near the inner margin, one across the cell and the other outside it, and with two silver-centered dark brown ocelli marginally in spaces M_2 - M_3 and M_3 - Cu_1 along a thin, wavy, silver marginal band extending from spaces Rs - M_1 to Cu - Cu_2 . The fringes are uniformly dull brown above and tan beneath on both wings. The length of the forewing of the Holotype ♂ is 16 mm.

The male genitalia bear little resemblance to those of *freemani* but are rather close to those of *hilaria*, especially as regards the straighter uncus and the blunter valvae. The valvae of *freemani* are tapered to a point (Fig. 4). For comparison the valva of *hilaria* is shown in Fig. 5.

Female: — Unknown.

Holotype ♂: — 52 mi. E. of Ciudad Victoria, Tamaulipas, MEXICO, 510 m., 7 Jan. 1966 (C. M. — C. U. A. expedition); L. D. Miller specimen no. 1966-119; ♂ genitalia slide no. 1496 (Lee D. Miller). The Holotype is in the collection of Carnegie Museum.



Figs. 3-5, ♂ genitalia of *Cyllopsis*. Fig. 3, *C. dospassosi*, new species, ♂ genitalia of Holotype. Fig. 4, *C. gemma freemani* (Stallings & Turner), valva. Fig. 5, *C. hilaria* (Godman), valva.

I take great pleasure in naming this distinctive species for Dr. C. F. dosPassos of Mendham, New Jersey, who was in part responsible for the expedition. His work has put him in the forefront of American lepidopterists.

Cyllopsis dospassosi is totally unlike *freemani*, *pyracmon* (Butler), or any of the other species previously recorded from so near the United States, as shown by both the pattern and the genitalic structures. The present species is most closely allied to *hilaria*, *pephredo* (Godman) and their relatives, but it may be distinguished immediately by the grayer upper surface and the olive-tan under surface with no trace of the rust color that characterizes the rest of the *hilaria*-group. The male genitalia differ in only minor respects from those of *hilaria*, but such close correspondence in the terminalia of closely related species is the rule in *Cyllopsis*. The Holotype of *dospassosi* was collected in the tropical deciduous forest perched in a brush pile at the edge of the dense woods. This species should be sought in other suitable habitats in Tamaulipas, particularly further south in the Sierra de Tamaulipas proper, and in the low coastal hills of northern Veracruz. There is a remote possibility that *dospassosi* may be found in southern Texas if suitable habitat for it can be found.

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HABITAT: *PIERIS BECKERI*

Pieris beckeri has more than one food plant. In certain areas in the Great Basin and in southern California the larvae are restricted to mustards but in other areas, they are restricted to a member of the Capparidaceae, namely, *Isomeris arborea*. The ability of this plant to remain green when all else has dried up probably accounts for the existence of adults of this species flying in the dry washes and hills of desert habitats late in the season.

The photographs were taken near Caliente, Kern Co., Calif. early July, 1969.

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IDENTITY OF THE MOTH
"STRETCHIA" BEHRENSIANA (GROTE)
WITH NEW SYNONYMY
(NOCTUIDAE)

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UNTIL PRESENT TIMES, "*Stretchia*" *Behrensiana* (Grote) has been considered a mystery. It was the author's intention to bring this matter into print years ago, but the manuscript was misplaced until recently.

"*Stretchia*" *behrensiana* is a name that is representative of an uncommon form of the species concerned, and as *Orthosia macona* (Smith) is the more recent name representing the same entity, it will have to fall into synonymy of *behrensiana*. The primary clue which led to the proper identification of *behrensiana* is the colored illustration presented by Hampson (1905). Until this colored illustration of the type female (pl. 89, fig. 10) of *behrensiana* was properly associated, the name had been applied to several genera, none of which are correct by present day concepts. The moth concerned is a typical *Orthosia*, and therefore it is placed as a new combination within *Orthosia*.

In the past few years, a number of specimens have been collected in central California that match Hampson's (op. cit.) colored illustration of the type. Illustrated by figures 1-4, one can see the major range in the maculation of the primaries of *behrensiana*. Under the redescription, the variation in coloration of the imago is given.

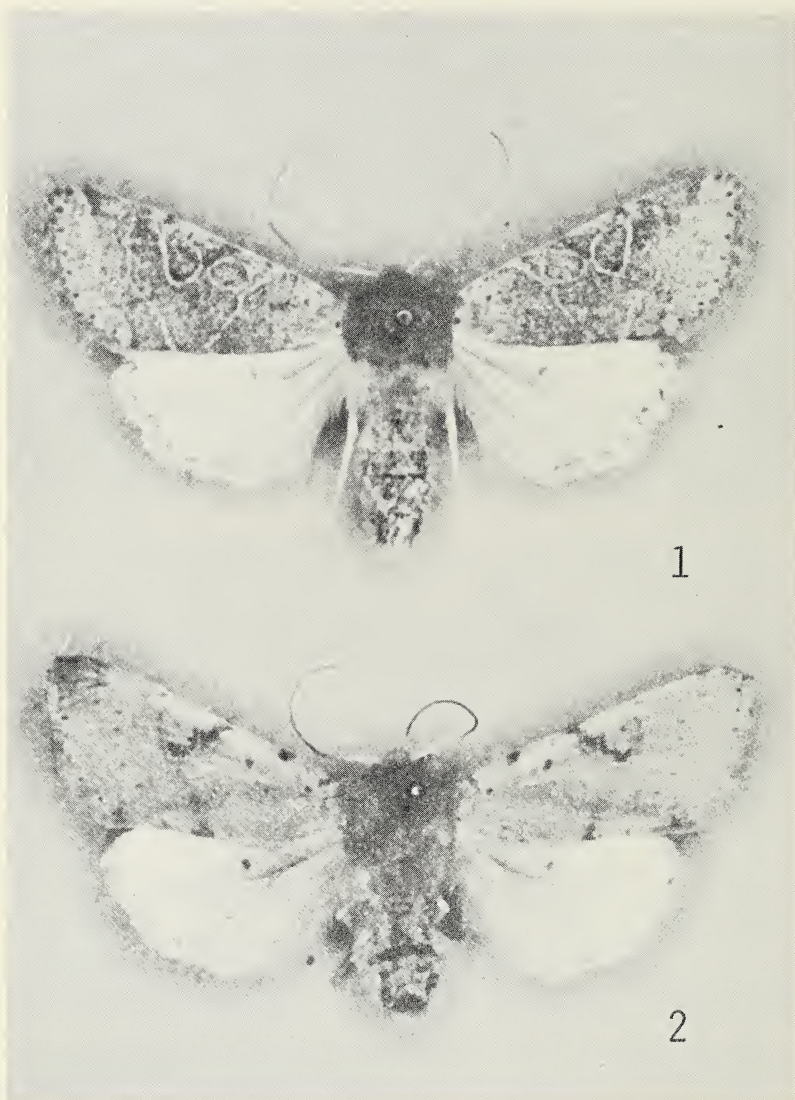


Fig. 1 *Orthosia behrensiana* (Grote), female. Anderson Springs, 4 miles northwest of Middletown, Lake County, California, 21 February 1954 (W. R. Bauer). This specimen matches type and is in the collection of the British Museum of Natural History, London.

Fig. 2 *O. behrensiana*, female. Cobb Mountain, Lake County, California, 12 February 1955. (W. R. Bauer and J. S. Buckett). This specimen also in British Museum of Natural History.

Orthosia behrensiana (Grote), New Combination
Graphiphora Behrensiana Grote, 1875. *Canad. Entomol.* 7(4):71-72.

Perigrapha behrensiana, Grote, 1881. *Canad. Entomol.* 13(6):133; Smith, 1889. *Proc. United States Nat. Mus.* 12:493-494.

Stretchia behrensiana, Smith, 1891. *Trans. American Entomol. Soc.* 13:120; 1893. *Bull. United States Nat. Mus.* No. 44, p.208; Dyar, 1903 (1902). *Bull. United States Nat. Mus.*, No. 52, p.167; Woodworth, 1912. *California Monthly Bull.* 1(10):789 (indicates *Xylomania*, after Hampson's concept); McDunnough, 1938. *Mem. Southern California Acad. Sci.* 1:75.

Xylomania behrensiana, Hampson, 1905. *Cat. Phalanae British Mus.* 5:390 plus pl. 89, fig. 10; Woodworth, 1912. *California Monthly Bull.* 1(10):789 (cites as a *Stretchia*, in italics).

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Taeniocampa macona Smith, 1908. *Ann. New York Acad. Sci.* 18(2), part 2: 102-103; Rindge, 1955. *Bull. American Mus. Nat. Hist.* 106(2):119.

Orthosia macona, Barnes and McDunnough, 1917. Check list of the Lepidoptera of Boreal America, p.54; Draudt (in A. Seitz), 1923. *The Macrolepidoptera of the World*, Div. 2, vol. 7, p.159; McDunnough, 1938. *Mem. Southern California Acad. Sci.* 1:76. New Synonymy.

Male: Ground color of primaries dorsally varying from pale tan to dark brown; secondaries dorsally off-white, irrorated with varying degrees of dark brown scales.

Head with vertex clothed in admixture of tan and dark brown elongate simple hairs; frons clothed in almost uniformly tan colored elongate simple hairs, integument evenly truncately rounded; labial palpi exterolaterally clothed in blackish scales and hairs, ventrally clothed in elongate tan and sparsity of black simple hairs terminal segment minute; antennae with scape and pedicle clothed in short, broad white to tan scales; flagellomeres biserrate-fasciculate, serrations becoming less pronounced terminally, dorsally clothed in tan simple, dentate scales.

Thorax with collar nearly unicolorous tan, composed of elongate simple hairs, terminal segment minute; antennae with scape and



Fig. 3 *O. behrensiana*, male. Summerland, Santa Barbara County, California, 24 January 1948 (C. W. Kirkwood).

Fig. 4 *O. behrensiana*, female. Ojai, Ventura County, California, 16 June 1957 (W. E. Simonds).

clothed anteriorly in blackish and tan elongate simple hairs, posteriorly clothed in off-white to tan elongate simple hairs; prolegs with femur and tibia clothed intero-laterally in smoky and tan simple scales and hairs; tarsus clothed in dark scales, terminally each tarsomere clothed in tan scales; meso- and meta-thoracic femora and tibiae clothed in tan elongate hairs and scales, extero-laterally with admixture of dark brown simple scales, tibial spurs one and two are meso- and metatibiae, respectively; primaries dorsally with pale tan to dark brown ground color; basal half line occasionally represented in either black or tan; transverse anterior line when present, geminate, centrally lighter than ground color, direction as in fig. 1; orbicular, when obvious, subcircular, may coalesce with reniform, tan or orangish-tan; median area of ground color, or median shade may be present (as in fig. 2); reniform suboval, smaller end pointed toward costa or apex, colored as in orbicular; transverse posterior line concolorous with transverse anterior line, direction as in fig. 1; subterminal space of ground color; subterminal line irregular in course when discernable, lighter than ground color; terminal line represented by black dots between veins; fringes more yellowish than ground color; ventral surface brownish, irrorated with black; reniform represented by black splotch; transverse posterior line brown; veins between transverse posterior line and fringes slightly outlined in tan; terminal line as in dorsal surface; secondaries dorsally off-white, basally slightly darker than apically; distal dot dark brown; terminal line dark brown (as in figures 1, 2, and 4); ventrally as in dorsal surface, except costal area darker.

Abdomen dorsally clothed in admixture of dark brown and tan simple scales; terminally clothed in tan elongate scales and simple hairs. Genitalia as in figures 5 and 6.

Greatest expanse of forewing 14-17mm.

Female: As in male, except for antennae which are ciliate, fasciculate; tendency for the "*behrensiana* form" by far greatest in this sex. Greatest expanse of forewing averaging slightly larger.

O. behrensiana is quite a variable species in dorsal maculation of the primaries. For this reason the correct name of the entity in concern has remained in confusion until recently. The species is widespread in California, ranging from San Diego County north into Del Norte County, and from sea level into the Sierra Nevada Mountains.



Fig. 5 *O. behrensiana*, male genitalia minus aedeagus; Bauer-Buckett Slide No. 68B27-50. Anderson Springs, Lake County, California, 21 March 1949 (W. R. Bauer).

Fig. 6 *O. behrensiana*, aedeagus of male genitalia. Data same as fig. 5.

Specimens of "*macona*" were sent to Dr. F. H. Rindge of the American Museum of Natural History, New York, where he graciously made type comparison with Smith's type of *T. macona*. The conspecificity of the specimens sent by the author with the type was confirmed.

Specimens of *behrensiana* were also sent for type comparison to Dr. I. W. B. Nye of the British Museum of Natural History, London. Unfortunately, the type female is lacking an abdomen, so genitalic comparison was impossible at this time; the type is otherwise in excellent condition.

I would like to extend my appreciation to both Dr. Rindge and to Dr. Nye for their cooperation in this project, and to Mr. George M. Buxton of this Bureau for the photographs contained herein.

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NOTICES

BOOKS:

BUTTERFLIES. A concise guide in colour. Josef Moucha, ill. by Vlastimil Choc. Paul Hamlyn, Hamlyn House, The Centre, Feltham, Middlesex. G.B.

BIOGEOGRAPHY OF THE SOUTHERN END OF THE WORLD. Philip J. Darlington, Jr. McGraw Hill paper back reprint, N.Y.

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THE JOURNAL OF RESEARCH ON THE LEPIDOPTERA

Volume 7

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STUDIES ON NEARCTIC *Euchloe*.

PART 5. DISTRIBUTION.

PAUL A. OPLER

University of California,
Berkeley, California

POPULATIONS OF THE NEARCTIC species of *Euchloe* occur from north of the Arctic Circle in Northwest Territories south to Baja California del Norte, Arizona, and New Mexico (30° North Latitude). In the west they occur to about 150° West Longitude in Alaska and to 80° West Longitude in Maryland to the east.

The four species of Nearctic *Euchloe* are single-brooded with one possible exception. Adults fly as early as January in San Diego County, California and as late as mid-August at high altitudes in Colorado.

Within the wide geographic and seasonal parameters mentioned above each species has narrower limits. The populations of each species possess flight period, behavior pattern, and host plant specificity characteristics that are met by only a small proportion of possible habitat spaces and times of the year. In this paper, I will summarize the information bearing on the distribution in time and space of *Euchloe creusa*, *Euchloe hyantis*, and *Euchloe ausonides*. A later paper will give in detail the distributional features displayed by populations of *Euchloe olympia* (Clench and Opler).

SEASONAL DISTRIBUTION

Populations of *Euchloe ausonides* found in the lowlands of central California appear to be at least partially double-brooded as has been shown by Sette (1958). The basis for this assumption of bivoltinism is the bimodal distribution for a large number of adults plotted against date of collection. Collection records of 317 individuals collected in the counties bordering San Francisco Bay are summarized in Figure 1. The small "second brood" can be produced due to the permissive climate and pres-

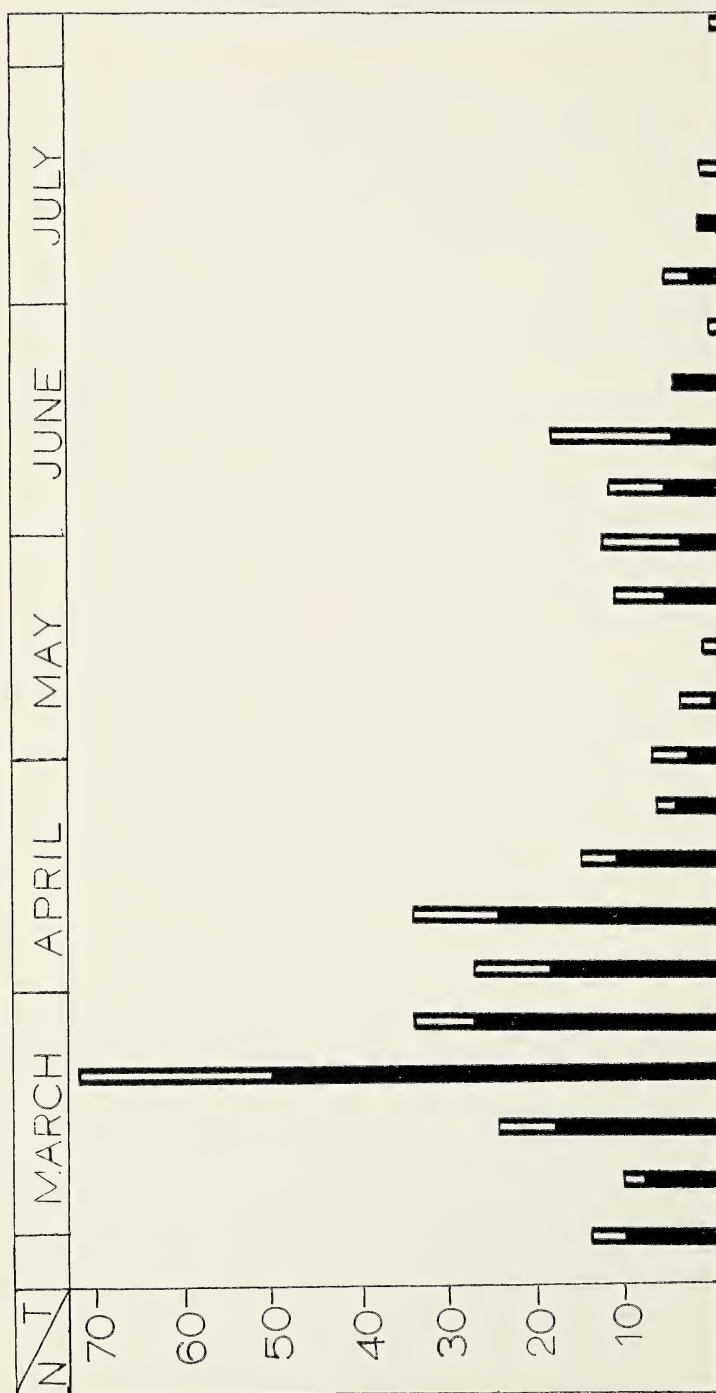


Fig. 1 Seasonal distribution of *Euchloe ausonides* in the San Francisco Bay Area, California. Solid portion of each bar represents number of males; open portion of each bar represents number of females.

ence of suitable host plants over a long period of time. Pupal diapause, which is normally obligatory for Nearctic *Euchloe*, must be facultative to allow those "second brood" individuals which do occur to complete development in the same year.

All other populations of *Euchloe* in the Nearctic Region are clearly single-brooded. The temporal distributions of all populations are determined by physical permissiveness of the environment and are coincident with the presence of appropriate cruciferous host plants in a suitable state of growth to serve as oviposition sites.

It is interesting to note the displacement of flight periods that occurs where *Euchloe ausonides* occurs in sympatry with or in proximity to each of the other three species. Populations of both *E. creusa* and *E. hyantis* can be seen to have earlier flight periods relative to *E. ausonides* in most instances. All examples of sympatry known to the writer are summarized below. Synchronic collections are also indicated.

SYMPATRIC OCCURRENCES WITH *EUCHLOE AUSONIDES*

Locality

Dates of capture (inclusive)

<i>Euchloe creusa</i>	Other species	Synchrony	<i>E. ausonides</i>
Whitehorse, Yukon Terr., CANADA	vi-9	vi-9-66	v-29 to vii-5
AlCan Highway, MP 855 Brit. Col., CANADA	vii-1	vii-1-66	vii-1
Atlin, Brit. Col., CANADA	vi-7 to vi-28		vi-20 to vii-7
Nordegg, Alberta, CANADA	vi-5		vi-25
Banff vicinity, Alberta, CANADA	v-29 to vi-30		vii-4 to vii-9
Prince Albert, Sask., CANADA	v-27 to vi-2	v-27-51 vi-2-51	v-27 to vi-2
<i>Euchloe olympia</i>			
Clear Ck. Cyn., nr. Golden, Jefferson Co., Colo.	v-10		v-26
Lefthand Cyn., Boulder Co., Colo.	v-30		v-25
Sunshine Cyn., Boulder Co., Colo.	v-4		iv-27 to v-5

Euchloe hyantis

Lilooet, Brit. Col.,	iv-20 to iv-28		vi-18 to vi-25
Cranbrook, Brit., Col.,	iv-18 to v-30		v-9 to vii-9
CANADA			
Alta Lake,	iv-29	iv-29-51	iv-29
Okanogan Co., Wash.			
Baker, Baker Co., Ore.	v-20 to v-21		v-27
Ontario, Malheur Co.,	iv-30	iv-30-41	iv-30
Ore.			
Eureka, Juab Co., Utah	v-7 to v-29		v-23
Salt Lake City,	v-?		iv-18 to vi-13
Salt Lake Co., Utah			
Jackson Hole,	v-16 to v-23	v-20-24	v-20 to vi-17
Teton Co., Wyo.		v-23-24	
Mt. Wheeler,	v-19/24	v-19/24-29	v-19 to vi-8
White Pine Co., Nev.			
2 mi. N Mt. Shasta City,	vi-25 to vii-3	vii-3-55	vii-3
Siskiyou Co., Calif.			
Cloverdale,	iv-25		iv-15
Sonoma Co., Calif.			
Hallelujah Jct.,	vi-17	vi-17-67	vi-17
Lassen Co., Calif.			
Mono Lake,	vi-17	vi-17-19	vi-17
Mono Co., Calif.			
6 mi. W. Lone Pine,	iv-9	iv-9-60	iv-9
Inyo Co., Calif.			

GEOGRAPHIC DISTRIBUTION

The geographic distributions of *Euchloe ausonides*, *creusa*, and *hyantis* are presented as figures 2, 3, and 4 respectively. More specific locality information is given in the citation of collection data.

Euchloe ausonides, the species with the widest range, occurs sympatrically with each of the other three species at some points in their distributions, the instances known to this writer are listed above. In each case of sympatry some altitudinal or ecological information not shown on collection labels probably occurs to cause effective allopatry in the sense of the niche occupied by each species.

ECOLOGICAL DISTRIBUTION

Although no intensive ecological studies have been conducted on species of *Euchloe* several statements on the ecological attributes which appear to be important in determining the presence or absence of populations of *Euchloe* can be made.

One apparent common denominator of all populations is that they occur in open areas. The other important parameter is the occurrence of populations only where some feature of relief in the landscape occurs. These two features seem to be required

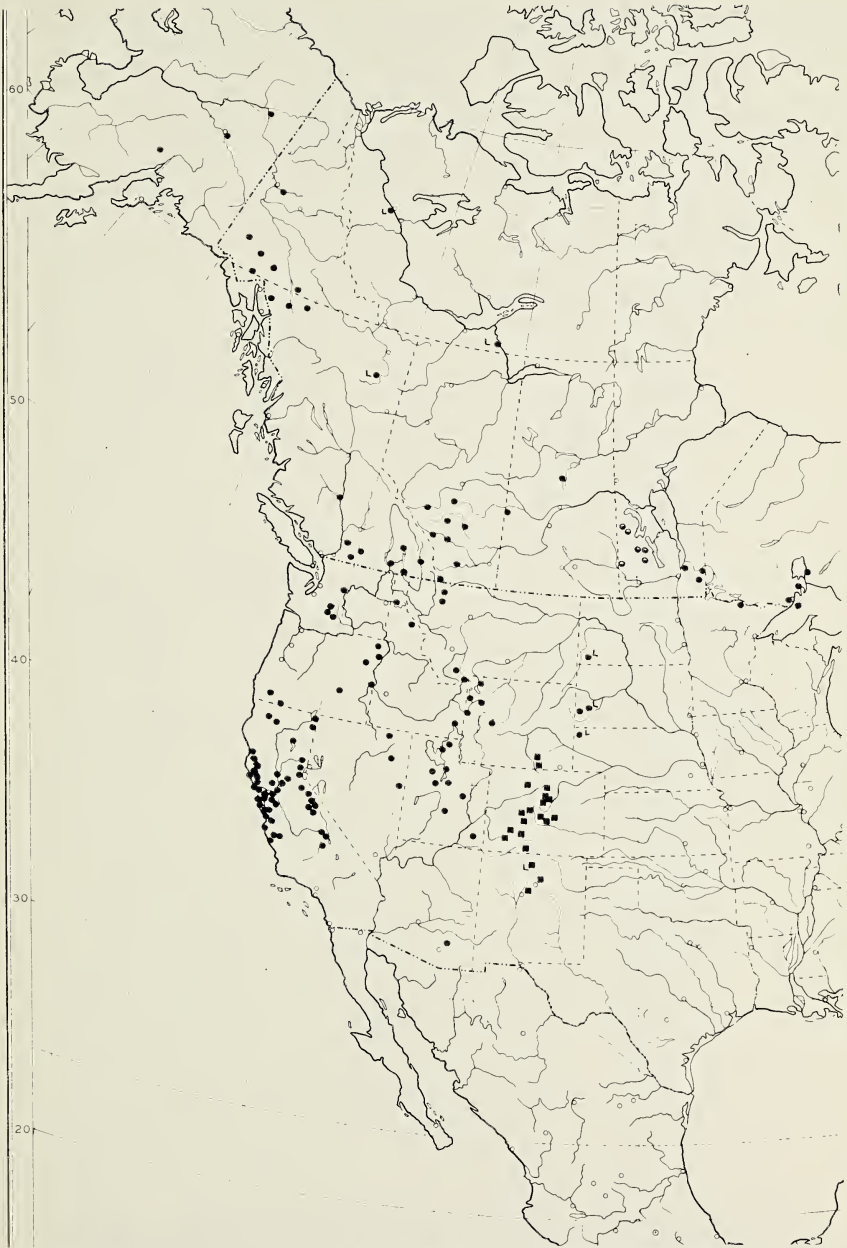


Fig. 2. Geographic distribution of *Euchloe ausonides*. Solid circles represent localities for nomenotypic *E. ausonides*, half-open circles represent localities for *E. ausonides mayi*, and solid squares represent localities for *E. ausonides coloradensis*. An "L" next to a symbol designates probable occurrences based on reports in the literature.

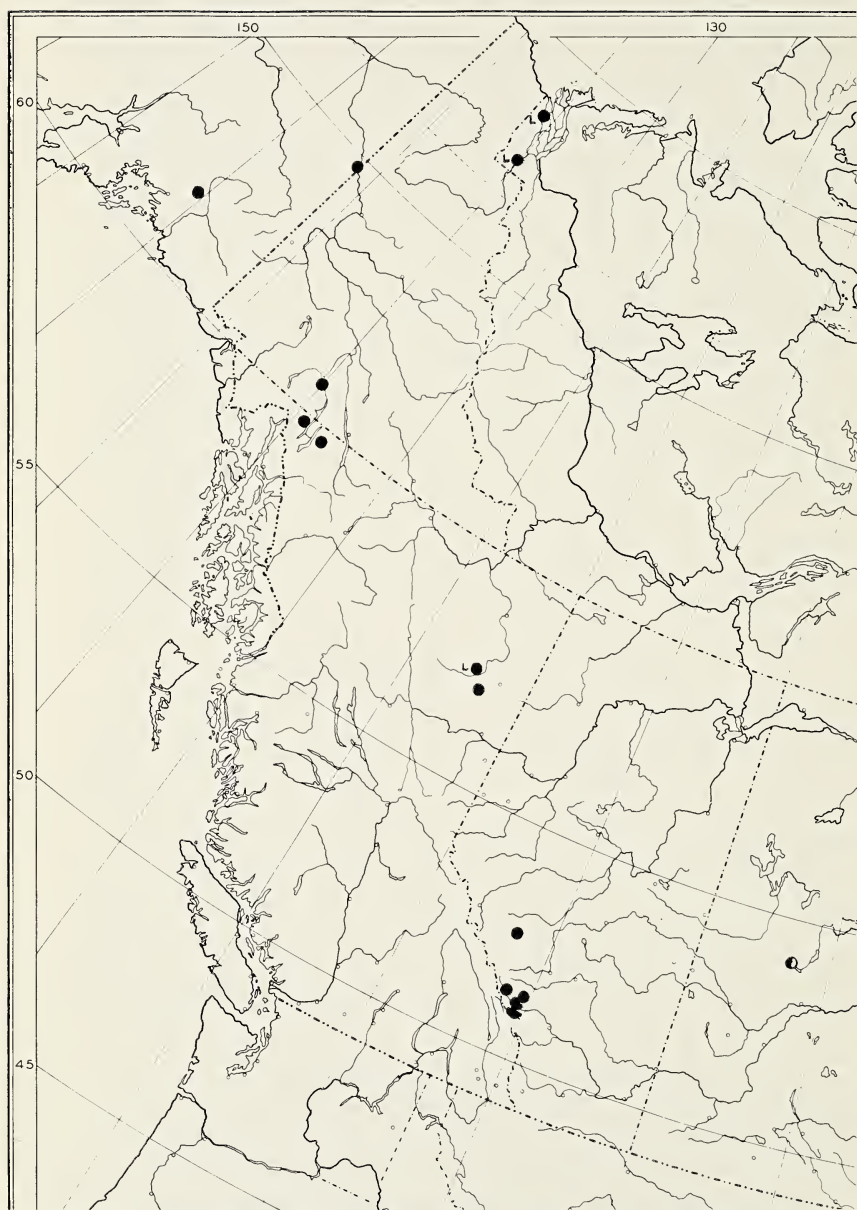


Fig. 3. Distribution of *Euchloe creusa*. Solid circles represent localities for the nomenotypic race; the half-open circle represents the occurrence of a distinctive segregate at Prince Albert, Saskatchewan.

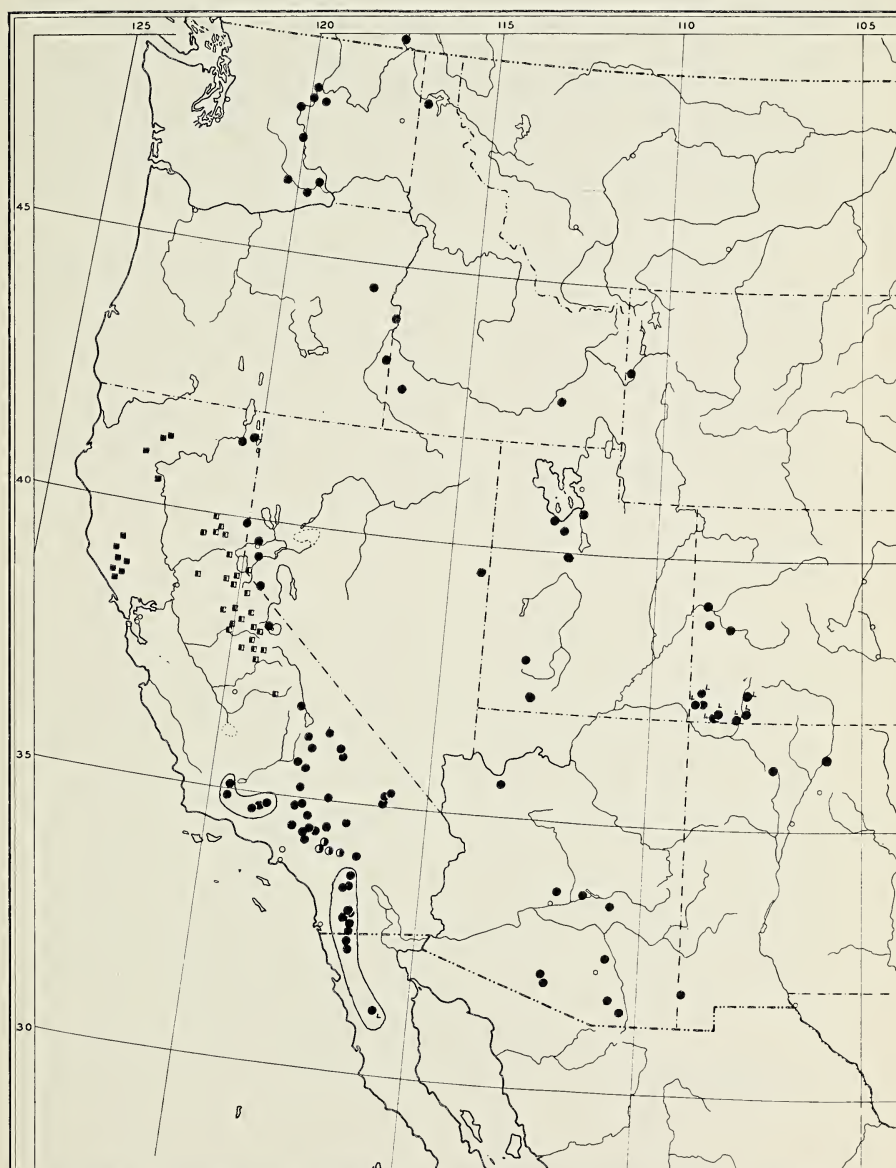


Fig. 4. Geographic distribution of *Euchloe hyantis*. Solid squares represent localities for the nomenotypic race; half-open squares represent the Sierra Nevadan populations; half-open circles represent localities for *E. hyantis andrewsi*; solid circles represent localities for all populations tentatively referable to *E. hyantis lotta*. The two groups of circles circled in black represent the "Mt. Pinos Block segregate" and the "Peninsular Ranges Segregate." Collection records for this species at Cranbrook and Oliver, British Columbia do not appear on this map.

to serve as keys to behavior patterns displayed by adults and to prevent loss of contact that might occur in "unbroken landscape." Thus, some populations appear keyed to "hill-tops," others to sunny, open areas on hillsides, and still others to river courses or dry stream beds. I have observed populations of *Euchloe ausonides* or *E. hyantis* keyed to each of these situations. The preferred habitat of *Euchloe creusa* in the vicinity of Banff, Alberta is on the talus slopes of lateral moraines.

It should be further noted that there appears to be ecological displacement whenever two species of *Euchloe* occur in close spatial proximity. This displacement may take the form of flight behavior, altitudinal occurrence, or host plant selection differences or any combination of the three. In areas where species of *Anthocharis* and *Pieris* occur with *Euchloe*, very complex interactions of an ecological nature must occur indeed. I believe that a proper description of the ecological characteristics of the crucifer feeding species of Pieridae in the Nearctic Region must await more careful field studies than have been made by this author.

SPECIMENS EXAMINED

The data for specimens seen during this study to date are listed below. For *Euchloe ausonides* in the vicinity of San Francisco Bay, California and for *Euchloe ausonides coloradensis* in Colorado where records are extremely numerous only county names and ranges of collection dates are given. Collections are abbreviated as follows: American Museum of Natural History (AMNH), David L. Bauer, (DLB), California Academy of Science (CAS), California Insect Survey, University of California (CIS), Glenn Gorelick (GG), John Lane (JL), Nevada State Museum (NSM), J. W. Tilden (JWT), Los Angeles County Museum (LACM), Noel La Due (NLD), Oakley Shields (OAS), Fred Thorne (FT), and Paul Opler (PAO).

LITERATURE CITED

CLENCH, H. K. and P. A. OPLER, in preparation. Bionomics of *Euchloe olympia*.

Euchloe ausonides ausonides

CANADA. - ALBERTA. vic. Banff, ♀, vii-4/9-30 (J. F. May, AMNH); Calgary, 7♂♂, 3♀♀, vi-1-03, vi-4-?, vi-6-03, vi-13-?, vi-14-?, vi-20-?, vi-27-?, vii-3-04, vii-8-04 (C. Garrett, AMNH); Carbon, 4♂♂, 3♀♀, v-31-?, vi-6-?, vi-23-04, vi-27-? (C. Garrett, AMNH); Didsbury, 3♂♂, ♀, vi-7-?, vi-10-06, vi-16-? (C. Garrett, AMNH); Lacombe, 2♂♂ (J. A. Comstock, LACM); Lethbridge, 1♂, vi-3-29 (J. H. Pepper, AMNH); Nordegg, 1♂, vi-25-21 (J. McDunnough, AMNH); Waterton Lakes, 2♀♀, vi-27-23, vi-21-23.

BRITISH COLUMBIA. Alaska Highway, MP836, 1♀, vii-1-66 (J. Lane, JL); Alaska Highway, MP 855, 1♂, 1♀, vii-1-66 (J. Lane, JL); A tlin, 1♂, vi-22-? (AMNH); Atlin, Wilson Crk., 1♂, 1♀, vi-20-14, vi-22-14 (AMNH); Atlin, 3♂♂, vi-27-29, vii-3-29 (G. Swarth, CAS); Cranbrook, 9♂♂, v-9-12, v-15-10, v-22-10, vi-12-?, vi-13-17, vi-15-?, vi-27-?, vii-2-?, vii-9-? (C. Garrett, AMNH); Creston, 2♂♂, vii-4-?, vii-12-? (AMNH); Lillooet, 1♀, vi-18/25-30 (Herr, AMNH); Nelson, 2♂♂, 1♀, v-9?, vi-7-? (AMNH); Princeton, 1♀, vi-?-43 (T. Menzies, CAS); 25mi. N. Princeton, 3400', 1♂, vii-27-66 (J. Lane, JL); Robson, 1350', 2♂♂, v-?-34 (AMNH); Robson, 3♂♂, iv-20-41, iv-30-39, v-31-39 (H. F. Foxlee, AMNH); Summerland, 1♂, v-31-? (AMNH); MANITOBA. Brokenhead, 7♂♂, 5♀♀, v-22/vi-4-36, vi-3-30 (AMNH, LACM); Red Rock Lake, Whiteshell Provincial Park, 1♂, 3♀♀, v-24-55, v-29-53, vi-13-54 (C. Bird, AMNH); Sandilands Provincial Forest, 8mi. SE Richer, 6♂♂, v-28-67 (J. H. Masters, PAO). ONTARIO. 3 mi. E. Beardmore, 3♂♂, vi-1-58 (P. D. Syme, AMNH); Ft. Williams, 1♀, vi-8-61 (G. Perrons, AMNH); Neebing, 1♂, ?-?-61 (W. Hartly, AMNH). SASKATCHEWAN. Nesbit Prov. Forest, Prince Albert, 2♂♂, 3♀♀, v-27-51, vi-2-51 (Aschim, AMNH); Rivercourse, 1♀, 2♀♀, v-24-41, v-25-41 (AMNH). YUKON TERRITORY. Alaska Highway, MP 1032, 3000', 1♀, vii-15-66 (J. Lane, JL); Alaska Highway, MP 1105, 2400', 2♀♀ (P. R. Ehrlich, AMNH); Whitehorse, 1♂, vii-5-30 (D. Fraser, AMNH), 14♂♂, 16♀♀, vi-6/9-23, vi-27-33 (J. A. Kusche, AMNH), 11♂♂, 4♀♀, v-29/vii-1-66 (J. A. Ebner, PAO).

UNITED STATES. - ALASKA. Alfred Creek Camp, 1♂, vii-15-22 (Pope, LACM), 1♂, 1♀, vi-4-02 (AMNH); Fort Yukon, 1♂, vi-12-17 (CAS), 2♂♂, 4♀♀, vi-?-19 (J. A. Kusche, LACM); Forty Mile Highway, 44 miles from east end, 1♀, vii-14-66 (J. Land, JL); Haine's Highway, MP 93, 1♂, vii-5-52 (Carson, AMNH); McKinley National Park, 27♂♂, 18♀♀, vi-13/21-31 (F. Morand, AMNH, LACM); Taylor Highway, Dawson Jct., 3500', 1♂, vii-4-55 (P. R. Ehrlich, AMNH). ARIZONA. PIMA CO. : Bear Canyon, 1♂, iv-9/17-31 (L. Martin, AMNH). CALIFORNIA. ALAMEDA CO. : (many records, see fig. 1). ALPINE CO. : rocks over Carson Pass, 8400', 2♂♂, vii-2-62, vii-4-63 (N. La Due, NLD). CONTRA COSTA CO. : (Many records

see fig. 1). EL DORADO CO.: China Flat, 5000', 1♂, vi-28-48, (W. E. Kelson, CIS). FRESNO CO.: nr. Rae Lakes, 11,000', 1♂, vii-22-35 (C. W. Anderson, CIS). INYO CO.: Alabama Hills, 6 miles west Lone Pine, 1♂, iv-9-60 (R. L. Langston, CIS). LAKE CO.: Clear Lake, 1♀, v-17-65 (G. Gorelick, GG). MARIN CO.: (Many records, see fig. 1). LASSEN CO.: 1 mi. W. Hallelujah Jct., 1♂, vi-18-67 (G. Gorelick, GG). MODOC CO.: Cedar Pass, 6350', vii-15-65 (R. L. Langston, CIS), 1♀, vi-26-58 (J. W. Tilden, JWT); Willow Ranch, 1♂, vii-10/20-28 (AMNH). MONO CO.: nr. Monitor Pass, 1♂, vi-23-62 (J. Powell, CIS); Mono Lake, 1♂, vi-17-19 (AMNH); Silver Lake, 2♂♂, v-17-36, vi-9-35 (LACM). MONTEREY CO.: 5 mi. S. Big Sur, 2♂♂, v-10-58 (P. A. Opler, PAO); Carmel Vy., Hasting's Reservation, 2♀♀, v-10-59 (P. A. Opler, PAO); Carmel Vy., Tularcitos Ranch, 1♀, iv-27-55 (J. Powell, CIS); Chew's Ridge, nr. Carmel, 2♂♂, vi-3-31 (LACM). NAPA CO.: Calistoga, 1♀, v-6-16 (W. N. Whole, CAS); Mt. Veeder Rd., 1♂, iv-27-58 (P. A. Opler, PAO); 3 mi. W. Oakville, 1♀, v-30-60 (P. A. Opler, PAO). NEVADA CO.: Wolf Creek, 1400', 1♀, iv-23-63 (N. La Due, NLD). PLACER CO.: 3 mi. W. Auburn, North Fork American River, 2♂♂, iv-9-57, iv-22-63 (N. La Due, NLD); Lake Tahoe, 1♀, vii-2-30 (CIS); between Roseville and Rocklin, 200', 1♀, iv-11-61 (N. La Due, NLD). PLUMAS CO.: Beckworth Pass, 1♂, vi-18-67 (G. Gorelick, GG); Half Moon Lake, 1♂, vii-2-67 (G. Gorelick, GG), 1♀, vi-6-61 (N. La Due, NLD); Coloma Road, south of Fair Oaks, 10♂♂, iii-13-61 (N. La Due, NLD); Fair Oaks, 2♂♂, iii-24-59, iv-16-58 (N. La Due, NLD); south of Fair Oaks, 5♂♂, 3♀♀, iii-12-62, iii-14-61, iii-20-61, iii-21-60, iv-9-62, iv-15-58 (N. La Due, NLD); 7 mi. S. Isleton, 1♂, iv-1-50 (R. L. Langston, RLL); North Sacramento, 2♀♀, iv-5-60, v-26-59 (N. La Due, NLD); Rancho Cordoba, 5♂♂, iv-60 (L. C. Clarke, PAO). SAN FRANCISCO CO.: (many records, see fig. 1). SAN JUAQUIN CO.: 5 mi. SE Tracy, 1♀, v-36-44 (R. Smith, CIS). SAN MATEO CO.: (many records, see Fig. 1). SANTA CRUZ CO.: Santa Cruz, 1♂, 4♀♀, iii-3-31, iv-7-38, iv-10-38, vi-8-31 (W. C. Wood, AMNH). SISKIYOU CO.: Gazelle, 2♀♀, vi-24-58 (F. Powell, CIS); Shasta Mdw., 2 mi. N. Shasta City, 3♂♂, vii-3-58 (N. La Due, NLD). SOLANO CO.: Glen Cove, Carquinez Strait, 3♂♂, vi-2-66, vi-5-65 (R. L. Langston, PAO, CIS); Vallejo, 2♂♂, 3♀♀, vi-2-62, vi-8-63 (R. L. Langston, CIS). SONOMA CO.: Cloverdale, 2♂♂, 1♀, iv-15-56 (R. P. Allen, CAS, CIS); Eldredge, 2♂♂, 2♀♀, v-16-17, iv-2-17 (J. A. Kusche, LACM); Healdsburg, 1♂, iii-25-53 (R. P. Allen, CIS); Jenner, 1♂, vii-2-59 (R. L. Langston, CIS); 2 mi. S. Jenner, 1♀, iv-24-60 (P. A. Opler, PAO); meadows east of Mark West Springs, 1♂, v-9-60 (N. La Due, NLD); Petaluma, 1♂, 1♀, v-26-49 (R. P. Allen, CIS); Petrified Forest, 1♀, iv-25-61 (La Due, NLD);

Russian River, 2♂♂, iii-23-33 (J. A. Comstock, LACM).
 MENDOCINO CO.: hills west of Boonville, 1♀, vi-1-57 (J. A. Powell, CIS). TULARE CO.: South Fork Kern River, nr. Deer Mountain, 1♂, v-31-47 (C. Smith, CIS). TUOLUMNE CO.: Locality unknown, 1♂, vii-21-30 (Bohart, CAS); Sonora Pass, 9600', 1♂, vii-5-65 (N. La Due, NLD); Sonora Pass, Deadman Creek, 3♂♂, 1♀, vii-3-59 (P. A. Opler, PAO); Tioga Pass, Yosemite N. P., 2♂♂, 2♀♀, vii-13/16-34 (AMNH). YOLOCO.: Knight's Landing, 1♀, v-?-54 (N. La Due, NLD); 10 mi. W. Winters, Putah Ck., 1♀, v-24-66 (P. Opler, PAO); Yolo Eypass, nr. Eryte, 2♂♂, iv-6-48, 1♂, iv-11-48 (C. D. MacNeill, CIS); Yolo Bypass, nr. Davis, 1♂, iv-20-30 (C. W. Herr, AMNH); Priest R., 1♂, v-9-27 (AMNH), 2♂♂, v-10/19-26 (C. W. Herr, AMNH). CARIBOU CO.: Soda Spgs., 1♂, 1♀, vi-23/24-33 (G. H. and J. L. Sperry, AMNH). SHOSHONE CO.: Wallace, 1♂, v-17-25 (AMNH). MINNESOTA. ST. LOUIS CO.: Ash River Trail, 1♂, vi-17-67 (J. H. Masters, POA). MONTANA. GLACIER CO.: Ptarmigan Tunnell, Glacier N. P., 7200', 1♂, vii-26-64 (J. G. Edwards, JGE); Swiftwater L., Many Glacier Chalet, Glacier N. P., 1♀, vii-4-30 (E. C. Van Dyke, CAS). NEVADA. ELKO CO.: vic. Arthur, 1♂, vi-20/30-29 (E. Schiffel, AMNH); Jarbidge Mts., 1♂, 1♀, vii-12-64 (J. Lane, JL); Wells, 1♂, v-23-54 (M. Cazier, AMNH). WHITE PINE CO.: Mt. Wheeler, 17♂♂, 13♀♀, v-19/24-29, v-30-29, vi-2/6-29, vi-8/10-29 (F. W. Morand, AMNH). OREGON. BAKER CO.: Baker, 3300', 1♂, v-27-57 (J. H. Baker, AMNH); Pine Ck., 4100', 1♀ vii-7-57 (tilden, JWT). HARNEY CO.: Devine Cyn., Hwy. 395, 12 mi. NNE Burns, 4800', 1♂, vi-1-65 (R. L. Langston, RLL). JACKSON CO.: Siskiyou Summit, 4522', 1♂, vii-2-58 (R. L. Langston, CIS). JOSEPHINE CO.: Green Mtn. Spgs. Summit, 1♀, vi-10-64 (Tilden, JWT). MALHEUR CO.: Ontario, Huntington Rd., 1♂, iv-30-41 (CAS). WALLOWA CO.: Chief Joseph Mtn., 2♀♀, vii-4-52, vii-8-52 (Sperry, AMNH); Joseph, 4500', 2♀♀, vii-?-54 (N. Crickmer, AMNH); Wallowa L., 4500', 1♂, 1♀, vi-14-39 (CAS). SOUTH DAKOTA. LAWRENCE CO.: vic. Clayton Draw, 6500', 6♂♂, vi-17-67 (J. Nordin, PAO); Spearfish cyn., 3♂♂, 2♀♀, vi-26-39, vii-1-? (AMNH). UTAH. CACHE CO.: Logan, 1♂, vi-12-33 (AMNH). DAVIS CO.: Mueller Park, 5600', Wasatch Mts., 6♂♂, 2♀♀, v-16-63, v-18-63 (K. Tidwell, OAS); Mueller Park, 5400', Wasatch Mts., 1♂, v-2-63 (K. Tidwell, OAS). ELDER CO.: nr grigham, 1♂, 2♀♀, vii-7/8-25 (LACM). EMERY CO.: Mohrland, 1♂, vi-23-? (O. S. Johnson, AMNH). JUAB CO.: Eureka, 1♂, v-23-20 (T. Spalding, AMNH). SALT LAKE CO.: Salt Lake City, 2♂♂, iv-18-43 (T. B. Ziegler, AMNH); Salt Lake City, City Creek, 6♂♂, 1♀, iv-22-40, v-11-30, vi-13-44 (CAS, LACM). SAN JUAN CO.: La Sal Mts., Burro Pass, 10,500', 1♂, vii-22-36 (AMNH); La sal Mts., Gold Hill, 10,600', 1♂, 1♀, vii-11-33 (A. G. Richards, jr., AMNH). SEVIER CO.: Fish L., 1♂, vii-17-49 (Gertsch, AMNH). TOOELE CO.: 13 mi. SW Grantsville, Loop Camp, 7400', 1♂, vii-3-60 (Rindge, AMNH). UTAH CO.: Dividend, 1♂, v-7-? (T. Spalding, AMNH); Payson

Cyn., 3♂♂, vi-19-33, vi-22-33, vii-7-33 (AMNH); Provo, Slate Cyn., 1♂, v-14-19 (Spalding, AMNH); Vineyard, 2♂♂, 2♀♀, v-22/24-22 (T. Spalding, AMNH). WASHINGTON. OKANAGAN CO.: Alta L., 2♂♂, iv-29-51 (A. Anderson, RLL). YAKIMA CO.: Bear Cyn., 2800', 2♂♂ (E. J. Newcomer, AMNH); Bear Cyn., 3200', 1♂, vi-17-62 (E. J. Newcomer, AMNH); Little Naches R., 1♀, v-29-59 (E. J. Newcomer, AMNH); Mill Ck., 1400', 1♂, iii-31-62 (E. J. Newcomer, AMNH); Mill Ck., 1500', 1♀, v-16-62 (E. J. Newcomer, AMNH); Mill Ck., 1800', 1♂, iv-11-62 (E. J. Newcomer, AMNH); Oak Ck., 3000', 1♀, vi-13-62 (E. J. Newcomer, AMNH); Wenas Ck., 1800', 1♀, v-14-60 (E. J. Newcomer, AMNH); Wenas Ck., 2000', 4♂♂, iv-26-61 (E. J. Newcomer, AMNH). WYOMING. TETON CO.: Grand Teton N. P., 6700', 1♀, vi-30-53 (J. A. Ebner, RLL); Jackson Hole, 1♂, vi-17-49 (CAS); Jackson Hole, Moose P. O., 2♂♂, v-20-24, v-23-24 (A. B. Klots, AMNH); base of Teton Range, 1♀, vii-11-25 (LACM); Togwotee Pass, 2♂♂, vi-21-41 (CAS); Yellowstone N. P., Dunraven Pass, 1♂, vi-25-30 (VanDyke, CAS); Yellowstone N. P., Roosevelt Camp, 4♀♀, vii-26-30 (E. C. Van Dyke, CAS); Yellowstone N. P., Roosevelt Lodge, 1♀, vii-3-38 (E. C. Van Dyke, CAS); Yellowstone N. P., Tower Falls Rd., 1♀, vi-7-37 (CAS); Yellowstone N. P., west entrance, 1♀, vi-14-30 (E. C. Van Dyke, CAS). SUBLETTE CO.: Willow Ck. Rgr. Sta., 8000-8900', 1♂, vii-14-39 (Klots, AMNH).

Euchloe ausonides coloradenses (Hy. Edwards

COLORADO. county unknown: 4♂♂ (AMNH), 1♂, vii-25-55 (Renk, PAO), 1♂ (T. L. Mead, AMNH). BOULDER CO.: Boulder, 2♂♂, vi-8-22, vii-5-02 (AMNH, LACM); Four Mile Cyn., 1♂, vi-28-52 (D. Eff, JWT), 1♂, 2♀♀, v-6-62, v-28-61 (D. Eff, OAS); Gregory Cyn., 1♀, v-19-64 (D. Eff, OAS); Lefthand Cyn., 2♀♀, v-30-57, vi-8-57 (D. Eff, JWT), 1♂, v-25-57 (D. Eff, OAS); Magnolia Rd., 2♀♀, v-30-54 (D. Eff, JWT); Mesa Trail, Boulder, 1♂, v-12-54 (D. Eff, JWT); Packer's Gulch, 1♀, vi-8-57 (D. Eff, JWT), 3♂♂, 1♀, v-6-62, v-16-63, v-28-61 (D. Eff, OAS); Sunshine Cyn., 2♂♂, 1♀, iv-27-61, v-5-62 (D. Eff, OAS). CLEAR CREEK CO.: Beaver Ck., Hwy. U.S. 40, 1♂, vi-18-60 (J. Scott, OAS). 3♂♂, vii-6-61 (Rindge, AMNH). DOLORES CO.: Rico, 1♂, vii-?-? (Oslar, AMNH); Rock Ck., vic Colorado Springs, 8500-8700', 6♂♂, vi-5-38, vi-26-41, vi-30/vii-4-39, vii-4-38 (A. B. Klots, AMNH). GILPIN CO.: Hideaway Park, 8715', 1♀, vi-23-54 (L. Martin, LACM). GUNNISON CO.: Almont, 2♂♂, 1♀, vi-20/30-25 (AMNH); 10-20 mi. SE Crested Butte, Cement Ck., 9800-11,000', 1♂, 1♀, viii-8-61 (Rindge, AMNH). JEFFERSON CO.: Clear Ck. Cyn., 1♀, v-26-63 (D. Eff, OAS); Golden, Chimney Gulch, 1♂, iv-20-04 (Oslar, AMNH); Indian Hills, 1♂, v-14-38 (AMNH); Mother Cabrini Shrine, 1♀, vi-18-60 (J. Scott, OAS). LARIMER CO.: Estes Park, 2♂♂, 1♀, vi-10-44, vi-16-44 (CAS); Long's Peak, 2♂♂, vi-15-22 (AMNH); Red Feather

Lakes, 8000', 4♂♂, vi-19-29 (A. B. Klots, AMNH); Rocky Mtn. N. P., 3♂♂, vi-?-31 (J. L. Sperry, CAS, LACM), 1♂, viii-15-37 (A. B. Klots, AMNH), 1♂, 2♀♀, vii-3-35 (L. Hulbirt, JWT). MINERAL CO.: locality unknown, 1♂, vii-1-40 (AMNH). PARK CO.: Elk Ck., 8500', 1♂, vi-4-60 (J. Scott, OAS); Hall Vy., 1♂, vi-15-02 (LACM); Hall Vy., 10,00'-10,500', 4♂♂, 1♀, vii-2/3-41, vii-13/15-35 (A. B. Klots, AMNH); South Park, 1♂, vii-29-04 (Oslar, AMNH). ROUTT CO.: Steamboat Springs, 6000', 1♂, vii-4-50 (Lot, CAS). SAN MIGUEL CO.: Ophir, 1♂, vii-?-14 (AMNH); San Miguel, 1♂, (Oslar, AMNH); Telluride, 1♂, vi-15-04 (LACM); Telluride, Cornet Ck., 11,000', 1♂, vii-9-19 (AMNH). SUMMIT CO.: Fremont Pass, 11,316', 1♂, 1♀, vi-22-54 (Martin, LACM). TELLER CO.: Green Mtn. Falls, 10,000', 2♂♂, vii-1/7-? (AMNH). NEW MEXICO, county unknown: Aspen Ranch, Sangre de Cristo Range, 9000', 1♂, vi-30-35 (A. B. Klots, AMNH). BERNALILLO CO.: San Antonio, 1♂, vii-9-36 (R. Kaiser, AMNH). SAN MIGUEL CO.: Cowles, Windsor Cyn., 8000-8500', 1♂, 1♀, vii-3-35 (A. B. Klots, AMNH). WYOMING, ALBANY CO.: Centennial, Univ. Wyoming Camp, 9600', 9♂♂, 8♀♀, vi-26/vii-6-29 (A. B. Klots, AMNH, CIS); Woods Landing, 1♂, vi-18-55 (G. DeFoliart, JWT).

Euchloe ausonides mayi Chermock and Chermock

CANADA. - MANITOBA, Beulah, 2♂♂, vi-20-37 (AMNH); Duck Mountain Provincial Park, 1♂, 1♂, vii-1-36 (J. S. Nordin, PAO); Duck Mountain Provincial Park, vic. Ketchum Hill, 2♂♂, vii-15-67 (J. H. Masters, PAO); Herchman, mi. 412, 2♂♂, vi-23-32, vi-24-32 (AMNH); McCreaf, 1♂, vi-22-38 (AMNH); Riding Mts., 2♂♂, vi-18-37, vi-29-34 (F. H. and R. L. Chermock, AMNH) PARATYPES, 1♀, vi-8-36 (AMNH), 2♀♀, vi-27-32 (J. F. May, LACM); Riding Mts., Kelwood, 1♀, vi-12-31 (CAS), 1♂, 1♀, vi-2/26-29 (J. F. May, AMNH); Riding Mts., Trail to Grey Owl's Cabin, 6♂♂, vii-24-67 (J. H. Masters, PAO); Riding Mountain National Park, 1♀, vi-19-60 (J. F. May, AMNH) AMNH); Sand Ridge, 1♂, vi-11-? (AMNH) PARATYPE, 2♂♂, vi-26-36 (AMNH).

Euchloe creusa creusa (Doubleday)

CANADA. - ALBERTA, Banff, 1♂, vi-21-25 (G. P. Englehardt, AMNH), 1♂, v-29-22 (C. B. D. Garrett, LACM); vic Banff, 2♂♂, vi-21/31-29 (J. F. May, AMNH); Banff, Cascade Mtn, Amphitheatre, 7000', 1♀, vi-2 9-25 (O. Bryant, AMNH); Banff, Rundle Mtn., E face, 5000'-7000', 1♂, vi-25-25 (O. Bryant, AMNH); Bow Lake, 2♂♂, vi-7-23 (G. C. Hall, AMNH); Laggan, 1♂,

vii-1-17 (AMNH); Nordegg, 1♀, vii-1-66 (J. Lane, JL); Atlin, 6♂♂, vi-7-?, vi-20-?, vi-21-?, vi-28-? (AMNH). YUKON TERRITORY. Whitehorse, 1♂, vi-9-23 (LACM), 1♂, 1♀, vi-9-66 (J. A. Ebner, PAO).

UNITED STATES. - ALASKA. Eagle, 1♂, vi-8-36 (F. Grinnell, LACM); Klutina Lake, 2♂♂, v-15-50 (W. C. Frowne, DLB).

Euchloe creusa, Saskatchewan segregate

CANADA. - SASKATCHEWAN. Prince Albert, Nesbit Provincial Forest, 5♂♂, 3♀♀, v-27-51, vi-2-51 (Aschim, AMNH).

Euchloe hyantis hyantis (Edwards)

CALIFORNIA. HUMBOLDT CO.: locality unknown, 1♂, no date (Hy. Edwards, AMNH), 1♀ (Koebele, CAS). LAKE CO.: 9 mi. N Upper Lake, 1♂, iv-4-62 (Langston, RLL). MENDOCINO CO.: Hopland, 2♀♀, v-14-32 (CIS). SHASTA CO.: Redding, 1♂, 1♀, iii-2-63, iii-12-63 (D. L. Bauer, DLB). SISKIYOU CO.: Castle Lake, 2♂♂, 1♀, vii-12-58 (J. Powell, CIS); Lake Mountain, 1♂, vii-4-63 (P. A. Opler, PAO); nr. Mt. Shasta, 1♀, vi-10-41 (CIS); Selad, 1♀, v-8-59 (R. P. Allen, CAS); n mi. N Mt. Shasta City, 2♂♂, 1♀, vi-25-58 (J. Powell, CIS), 1♂, vii-3-58 (N. La Due, NLD). SONOMA CO.: locality unknown, 1♂, iv-17-38 (LACM); Cazadero, 1♂, 1♀, iv-17-30 (CAS, CIS), 1♂, 1♀, v-3-31 (W. C. Wood, AMNH), 2♂♂, 1♀, v-19-29 (Bohart, CAS); Cloverdale, 1♂, iv-25-57 (R. P. Allen, CAS); 2 mi. E Duncan Mills, 1♂, 1♀, vi-1-57 (R. L. Langston, RLL); Geysers, 1♂, v-10-38 (E. C. Johnston, AMNH), 1♂, iv-8-61 (Tilden, JWT), 1♂, iv-22-59 (M. Doudoroff, CIS); 3 mi. NE Guerneville, 2♂♂, iv-8-55 (Langston, RLL). TRINITY CO.: Trinity Center Delta, Trinity Mts., 1♀, v-22-25 (R. F. Sternitzky, AMNH).

Euchloe hyantis, Sierra Nevada segregates

CALIFORNIA. county unknown: Locality unknown, acc. no. 3576, 1♂, no date (Hy. Edwards, AMNH); Feather River, 7♂♂, 5♀♀, vii-4/18-28 (AMNH), 2♂♂, iii-25-32 (AMNH); Lake Tahoe, 1♂, vi-11-35 (AMNH), 1♂, vi-13-30 (R. F. Sternitzky, CAS), 1♂, v-29-30 (LACM); Sierra Nevada, acc. no. 4278, 1♂ (Hy. Edwards, AMNH); Yosemite, acc. no. 4278, 2♂♂ (Osten Sacken, AMNH); Yosemite N. P., 1♂, v-13-27 (CAS); Yuba River, 1♀, v-29-27 (CAS). ALPINE CO.: Hope Vy., 5♂♂, vi-9-48 (J. W. MacSwain, CIS). AMADOR CO.: peaks over Carson Spur, 8200', 4♂♂, vi-20-61 (N. La Due, NLD); rocks over silver Lake, 8000', 2♂♂, 1♀, vi-19-61, vii-2-62 (N. La Due, NLD). CALAVERAS CO.: Camp Wolfeforo, B. S. A., N. Fk. Stanislaus River, 5600', 2♀♀, vi-18-54, vi-21-54 (P. A. Opler, CAS, PAO); Dorrington, 2♂♂, iv-12-33 (CIS), 2♂♂, 1♀, vi-10-30 (AMNH); EL DORADO CO.: Echo Lake, 1♂, vii-22-63 (N. La Due, NLD); nr. Echo Lake,

2♂♂, 1♀, vii-6-40, vii-9-40 (CIS); Mt. Tallac, 9785', 1♂, vii-27-39 (F.H. Rindge, AMNH); Wright's Lake, 1♂, vii-2-48 (J.W. MacSwain, CIS). MARIPOSA CO.: w mi. n Bear Vly., Hwy. 49, 1♂, iv-17-61 (Opler, PAO), 1♂, 1♀, iv-26-65 (R.E. Stanford, Hughes-Stanford Coll'n); Boundary Hill, Yosemite, 1♂, vii-10-54 (R.P. Allen, CIS); El Portal, 3♂♂, 1♀, iv-11-64 (Opler, PAO), 2♀♀, iv-27-21, vii-2-21 Stanford-Highes Coll'n); Glacier Pt., 2♂♂, vi-28-21, vii-2-21 (J.A. Comstock, LACM); above Indian Flat, 21♂♂, 7♀♀, iv-14-63 (La Due, NLD); 1/2 mi. E May Lake, Yosemite N.P., 8900', 1♂, vii-4-46 (F.H. Rindge, AMNH); Tamarack Flat, Y.N.P., 1♂, vii-3-54 (Tilden, JWT); Wawona, 2♂♂, v-25-? (L.B. Woodruff, AMNH); Yosemite Vly., 3880-4000', 1♀, vi-1-38 (R.M. Bohart, CAS), 1♂, vi-3-38 (N. Hardman, AMNH). NEVADA CO.: Donner Pass, 1♂, vii-4-62 (J. Powell, CIS). PLACER CO.: locality unknown, 1♀ (AMNH), 3♂♂, 2♀♀, "June" (Koebele, CAS); nr. Auburn, N. Fk. American River, 800', 20♂♂, 4♀♀, iv-18-61, iv-21-63, iv-22-63, iv-23-62, v-1-67 (La Due, NLD); Mt. Judah, north slope, 2♂♂, vii-16-63, viii-6-63 (La Due, NLD). PLUMAS CO.: Feather River, 1♂, iii-25-30 (R. Wind, JWT). SIERRA CO.: Bassets, 1♀, vii-8-67 (Opler, PAO); Gold Lake, 2♂♂, 3♀♀, vii-14-21, vii-15-25, vii-16-21 (J.D. Gunder, AMNH), 2♂♂, vii-1-35, vii-10-35 (L. M. Martin, LACM); 1♂, vii-2-63 (La Due, NLD), 1♂, vii-19-67 (O. Shields, O OAS), 1♂, vii-8-67 (Opler, PAO); 3 mi. E Gold Lake, 1♂, vii-1-61 (D. Dirks, OAS); Salmon Lake, 2♂♂, vii-27-? (CAS); Shenanigan Flat, 2♂♂, vi-17-67 (Opler, PAO); Yuba Pass, 1♀, vi-28-60 (Tilden, JWT). TULARE CO.: Sequoia N.P., 1♂, iv-10-30 (CAS). TUOLUMNE CO.: Hog Ranch, 4600', 1 mi. E Mather, 1♀, vi-23-64 (O. Shields, OAS); nr. Sonora Pass, 5♂♂, 2♀♀, vi-20-47 (C.D. MacNeill, CIS); Strawberry Lake, 1♀, vi-10-32 (CAS); Tuolumne River, nr. Tuolumne City, 1♂, iv-17-61 (P.A. Opler, PAO), 1♂, iv-27-65 (R.E. Stanford, Hughes-Stanford Coll'n). NEVADA. DOUGLAS CO.: Kingsbury Grade, 1♀, vi-18-67 (Opler, PAO).

Euchloe hyantis, Mt. Pinos Block segregate

CALIFORNIA. KERN CO.: Lebec, 1♂, vii-8-56 (Opler, PAO); Sand Springs, 6000', 1♂, v-28-39 (Rindge, AMNH). VENTURA CO.: Chuchupate Rgr. Sta., 3♂♂, 2♀♀, v-1-59, v-5-59 (J. Powell, CIS), 1♂, 2♀♀, v-8-59 (P.D. Hurd, CIS), 4♂♂, v-14-60 (Spler, PAO); Cuyama, 1 Cuyama, 1♂, iv-8-58 (R.P. Allen, CIS).

Euchloe hyantis, Peninsular Ranges segregate

CALIFORNIA. RIVERSIDE CO.: Palm Springs, 1♂, iv-3-25 (E. P. Van Dyke, CAS); Pinyon Flat, 1♂, iv-20-62 (MacNeill, Rentz, and Brown, CAS), 3♂♂, iv-13-63 (Langston, RLL), 2♂♂, 1♂, iv-7-63 (Langston, CIS), 1♂, iv-12-63 (G. Tamaki, CIS);

Santa Rosa Summit, 7 mi. E Anza, 1♂, iv-18-62 (NacNeill, Rentz, and Brown, CAS). SAN DIEGO CO.: Agua Caliente, 4♂♂, 3♀♀, iv-6-50, iv-6-52, iv-14-51, iv-25-53 (Powell, CIS); 2 mi. SE Banner, 1♂, iii-31-63 (O. Shields, AOS); 3 mi. E Banner, 2500', 2♂♂, i-21-58, ii-9-58 (F. Thorne, PAO); Buckman Spring, 1♂, iii-14-63 (Powell, CIS); Descanso Rgr. Sta., 1♂, iii-30-61 (Langston, RLL); Horse Haven Gorge, Laguna Mts., 1♂, v-1-65 (O. Shields, AOS); Jacumba, 1♂, iv-9-52 (Powell, CIS); 3 mi. NW Jacumba, 1♂, 1♀, iii-31-63 (F. Thorne, PAO); 4 mi. E Jacumba, 3200', 1♂, iii-27-66 (O. Shields, AOS); Laguna Mtn. Recr. Area, 4♂♂, 1♀, iv-22-51, v-11-51 (Langston, RLL); Monument Peak, Laguna Mts., 3♂♂, v-11-52 (Langston, RLL); nr. Monument Peak, 1♂, iv-22-51 (Langston, RLL); Mt Laguna, 1♂, vi-21-63 (P. Welles, CIS); Pine Vy., 3600', 1♂, v-1-65 (O. Shields, AOS); Scove Cyn., 3 mi. N Mt. Laguna Jct., 1♂, iii-27-61 (Langston, CIS); Storm Cyn., Laguna Mts., 5500', 9♂♂, 1♀, iv-21/24-62 (F. Thorne, LACM, PAO).

Euchloe hyantis andrewsi Martin

CALIFORNIA. SAN BERNARDINO CO.: Cedar Pines, 1♂, v-13-28 (LACM); Crestline, 5000', 14♂♂, 2♀♀, v-26-40, vi-7-39, vi-10-49 (Rindge, AMNH), 5♂♂, 1♀ (W. T. Meyer, LACM, CIS, JWT); Crestview, 3♂♂, 1♀, v-24-42 (Rindge, AMNH); Fish Camp, 1♂, vi-18-36 (C. M. Dammers, LACM); nr Lake Arrowhead, 1♂, v-25-47 (C. Smith, CIS); nr. Lake Arrowhead, Crestline Hwy., 3♂♂, 2♀♀, v-19-35, 1♀, vi-15-36 PARATYPES, 7♂♂, 2♀♀, vi-8-36 TOPOTYPES (R. H. Andrews, LACM, JWT); Running Spring, 2♂♂, iv-2-40 (C. Smith, CIS), 1♂, v-25-47 (LACM); Sugarloaf Mtn., 8000', vic. Big Bear Lake, 1♂, vi-19-66 (J. Lane, JL).

Euchloe hyantis lotta Beutenmuller

CANADA. - BRITISH COLUMBIA. Cranbrook, 6♂♂, 5♀♀, iv-18-13, iv-19-13, iv-21-13, iv-27-13, v-2-10, v-5-10, v-30-11 (C. Garrett, AMNH); Lillooet, 2♂♂, iv-20-18, iv-28-17 (AMNH); Oliver, 2♀♀, iv-24/25-23 (AMNH).

UNITED STATES. - ARIZONA. GILA CO.: Globe 1♂, iii-30-41 (AMNH). MARICOPA CO.: Apache Lake, 1♂, iii-7-53 (G. W. Kirkwood, LACM). MOHAVE CO.: Peach Springs, 2♂♂, iv-12-40 (Rindge, AMNH). PIMA CO.: Brown Cyn., Baboquivari Mts., 1♀, iii-31-53 (L. M. Martin, LACM); Catalina Mts., 1♂ (AMNH); Fresno Cyn., Baboquivary Mts., 3♂♂, 1♀, iii-14-59 (K. Roever, JWT); Madera Cyn., 1♂, iii-28-61 (O. Shields, AOS), 4♂♂, 1♀, iv-2/3-53, iv-15-54 (L. M. Martin, LACM). SANTA CRUZ CO.: Patagonia, 2♂♂, iii-24-38 (CIS, JWT). YAVAPAI CO.:

Mingus Mtn., 1♂, iii-31-50 (D.L. Bauer, LACM). CALIFORNIA. INYO CO.: Aguerreberry Camp, 5320', 5♂♂, 1♀, iv-8-60, iv-20-58 (Langston, RLL); Alabama Hills, 6 mi. W Lone Pine, 8♂♂, 1♀, iv-9-60 (Langston, RLL); Alabama Hills, Tuttle Cyn., 3 mi. W Lone Pine, 1♀, iv-9-60 (Langston, RLL); Argus Mts., 2♂♂, 14♀♀, iv-?-1891, v-?-1891 (CAS); summit Argus Mts., Hwy. 190, 2♂♂, 2♀♀, iv-13-60 (Opler, PAO); nr. Haiwee Summit, 1♀, iv-1-47 (C. Smith, CIS); 5 mi. N Little Lake, 1♀, iv-10-62 (J.W. MacSwain, CIS); 9 mi. W Lone Pine, 1♂, iv-9-60 (Langston, RLL); Panamint Mts., 1♂, iv-?-1891 (CAS); 3 mi. E Skidoo, Panamint Mts., 5500', 1♂, iv-13-57 (Langston, RLL); Surprise Cyn., Panamint Mts., 1♂, iv-24-57 (J. Powell, CIS); Wild Rose Springs, Panamint Mts., 3500', 1♂, 1♀, iv-12-57 (Langston, RLL). KERN CO.: locality unknown, 1♀, iv-15-27 (J.S. Garth, AMNH); Mojave, 3♂♂, iv-15/17-38 (AMNH); 22 mi. E Mojave, 1♂, iv-1-26 (AMNH); 8 mi. W Mojave, 2♂♂, iv-11-58 (J.W. MacSwain, CIS); Red Cyn., Mojave Desert, 1♂, iv-18-30 (CAS); 9 mi. N Ricardo, east branch Last Chance Cyn., Hwy. 6, 1♂, iv-10-60 (C.A. Toschi, CIS); 5 mi. E Roamond, 1♂, iii-27-60 (K. Shea, PAO); Taft, 1♀, iv-?-? (AMNH) Walker Pass, 5200', 1♀, vi-17-67 (F. Thorne, PAO). LASSENCO : 1 mi. W Hallelujah Jct., 2♂♂, vi-17-67 (P. Opler, PAO). LOS ANGELES CO.: locality unknown, 1♂ (CAS), 1♂, v-?-? (CAS); Boquet Cyn., Sierra Madre Mts., 1♀, iv-12-25 (LACM); Desert Spgs., 2♂♂, v-7-63 (Langston, CIS); Littlerock, 11♂♂, 5♀♀, iii-17/25-28, iii-21/22-31, iii-21/iv-2-32, iii-25-33 (AMNH, CAS, LACM), 2♂♂, 3♀♀, iii-16-35, iv-12-36 (G. Heid, CAS), 3♂♂, 3♀♀, iv-6-39 (C. Smith, CIS); 2♂♂, iv-4-32 (R.W.L. Potts, CIS), 1♂, iv-?-36 (J. Fischer, RLL), 1♂, iv-20-50 (C.D. MacNeill, CIS), 35♂♂, 12♀♀, iii-28-64, iv-3/11-55, iv-9-60, iv-11/12-54 (P. Opler, PAO), 2♂♂, iii-25-59 (Tilden, JWT); nr. Littlerock, 2♂♂, iii-16-40 (C. Smith, CIS); nr. Littlerock Dam, 1♂, iii-30-41 (CIS); Llano, 3000', 1♂, iii-11-34 (LACM), 1♀, ii-15-37 (J.A. Comstock, LACM); Lovejoy Buttes, Mojave Desert, 2♂♂, iii-18-47, iv-6-41 (C. Smith, CIS); Mint Cyn., 4♂♂, 2♀♀, iv-18-34, iv-20-28 (AMNH, LACM); Palmdale, 3♂♂, iv-5-30, v-1-37 (AMNH), 1♀, iv-14-27 (J.S. Garth, CIS), 1♂, iii-21-47 (LACM); Switzers, w♂♂, 1♀, iii-21-32 (W. A. Evans, CAS); Valyermo, 1♀, iv-3-38 (AMNH), 6♂♂, iii-28-37, iv-28-35 (G. Heid, CAS). MODOC CO.: 6 mi. W Alturas, 2♂♂, 1♀, v-23-56 (Langston, RLL); Cedarville, 1♀, vi-4-35 (E. C. Johnston, AMNH). MONO CO.: Mono Lake, 1♂, vi-17-19 (AMNH). RIVERSIDE CO.: 1 mi. N Desert Center, 1♀, iv-11-58 (W.E. Ferguson, CIS); Split Rock Tank, 1♂, iii-22-39 (AMNH). SAN BERNARDINO CO.: Adelanto, 1♂, iii-20-31 (C.M. Dammers, LACM); Baldy Mesa, 1♀, iv-9-37 (J.A. Comstock, LACM); Barstow,

1♂, iv-8-31 (CAS); above Bonanza King Mine, Providence Mts., 2♂♂, iv-7-66 (P. Opler, PAO), 17♂♂, 7♀♀, iii-15-67 (G. Gorelick, GG); 16 mi. SW Cima, 5000', 9♂♂, 2♀♀, iv-2-66 (P. Opler, PAO); 1/2 mi. W Cotton wood Spring, 4000-5000', Granite Mts., nr. Essex, 4♂♂, iii-22-67 (O. Shields, AOS); Kramer, 1♂, iv-2-32 (AMNH); Mitchell Caverns, Providence Mts., 1♂, iv-10-52 (F. Thorne, FT); ridge just west of Mitchell Caverns State Park, 1♂, iv-14-65 (O. Shields, AOS); Paradise Vy., 2♂♂, 2♀♀ (CAS); Phelan, 5♂♂, 5♀♀, iv-10-38, iv-11-37, iv-15-33, iv-18-50 (AMNH, LACM), 3♂♂, 2♀♀, iii-28-35, iv-4-37, iv-13-35, iv-14-37 (F. Estes, AMNH), 5♂♂, 1♀, iii-20-31, iv-11-30, iv-18-30 (C. M. Dammers, LACM); 2 mi. S Phelan, 1♀, v-7-63 (CIS); Quail Springs, 1♂, iv-15-38 (AMNH); between Randsburg and Kramer, 10♂♂, 4♀♀, v-5-27 (T. Craig, CAS); San Bernardino, 1♀, iii-15-14 (V. L. Clemence, LACM); Sheep Ck., 5♂♂, 5♀♀, iv-22-28, iv-24-29 (LACM), 5♂♂, iii-20-31 (C. M. Dammers, LACM); Victorville, 2♂♂, 1♀, iv-18-31 (CAS), 1♂, 1♀, iv-15-57 (Tilden, JWT); Upper Volta, Phelan, 1♀, iii-6-33 (J. L. Sperry, CAS); Yucca Vy., 25 mi. W 29 Palms, 1♂, iv-8-55 (F. Thorne, FT). COLORADO. MESA CO.: Black Ridge, 1♂, v-10-46 (AMNH), 1♂, v-17-61 (D. Eff, AOS); Black ridge Breaks, Frita, 1♂, vi-5-44 (CAS); Black Ridge, Coal Mine Point, 3♂♂, v-11-63 (O. Shields, AOS), 2♂♂, v-17/18-61 (D. Eff, AOS); Decil's Cyn., 5000', 2♀♀, iv-23-40 (AMNH); Glande Park, 7000', 5♂♂, 2♀♀, iv-20-40 (AMNH). MONTEZUMA CO.: Mesa Verde, 1♂, iv-21-40 (LACM). IDAHO. ADA CO.: Kuna, 6♂♂, 3♀♀ (AMNH). BINGHAM CO.: Blackfoot, 2♂♂, iv-18-? (AMNH). BONNER CO.: Priest River, 1♂, vii-9-20 (AMNH). NEVADA. county unknown: 1♂ (AMNH). ORMSBY CO.: Eagle Valley, Carson City, 4700', 1♀, v-10-61 (P. Herlan, NSM). WASHOE CO.: Reno, 1♂, v-9-18 (LACM), 1♀, v-7-08 (F. Burns, LACM); hills 2 mi. N Reno, 1♂, vi-18-67 (P. Opler, PAO). WHITE PINE CO.: Mt. Wheeler, 4♂♂, v-19/24-29 (F. W. Morand, AMNH). NEW MEXICO. HILDALGO CO.: Rodeo, 1♂, 1♀, iii-9-38 (Tilden, JWT). RIO ARRIBA CO.: 1 mi. E Capulin, 11♂♂, 1♀, iv-11-63 (J. Scott, AOS); Embudo, 1♂, iv-21-62 (J. Scott, AOS). OREGON. BAKER CO.: Baker, 4♂♂, v-20-57, v-21-58 (J. H. Baker, AMNH). MALHEUR CO.: Huntington Rd., Ontario, 1♀, iv-30-41 (CAS); nr. Rockville, 1♂, v-18-61 (J. Baker, AOS). UTAH. BEAVER CO.: Beaver Ck. Hills, 3♂♂, v-?-?, v-?-? (AMNH). JUAB CO.: Eureka, 9♂♂, 1♀, v-7/21-11 (T. Spalding, AMNH), 1♂, 2♀♀, v-29-20 (LACM). SALT LAKE CO.: Salt Lake City, 1♀, v-?-? (AMNH). TOOELE CO.: Stockton, 3♂♂, iv-29-07, v-6-28, v-11-09, v-30-07, vi-8-06 (T. Spalding, AMNH, JWT); North Willow Ck., Stansbury Mts., 5400', 2♂♂, v-15-63 (K. Tidwell, AOS). WASHINGTON CO.: Zion N. P., 1♂, iv-18-27 (CAS). WASHINGTON, BENTON CO.: Prosser, 1♂, iv-25-21 (W. Lord, LACM); 10 mi. NW Richland,

3♂♂, iv-14-62 (R. E. Woodley, AOS). CHELAN CO.: Port Columbia, 1♀, iv-16-? (CAS). DOUGLAS CO.: Dyer Hill, 1♀, v-7-55 (PAO). OKANAGAN CO.: Alta Lake, 2♂♂, iv-29-51 (A. Anderson, RLL); Brewster, 16♂♂, 11♀♀, iv-20-32, iv-18-54, iv-19-58, iv-28-58, iv-30-60, v-1-60 (J. W. Hopfinger, AMNH, JWT); Pateros, 1♂, 1♀, v-2-33 (W. C. Wood, AMNH), 2♂♂, 1♀, iv-23-33, v-10-32, v-15-32 (AOS, CIS). YAKIMA CO.: Priest Rapids, 500', 9♂♂, 3♀♀, iv-2-62, iv-5/8-66 (E. J. Newcomer, AMNH, PAO). WYOMING. TETON CO.: Jackson Hole, 1♂, v-20-24 (AMNH); Jackson Hole, Moose P. O., 1♂, 2♀♀, v-16-24, v-20-24, v-23-24 (A. B. Klots, AMNH).

ADDEND A

Euchloe ausonides

CANADA. - ALBERTA. Banff, 1 ♀, vii-7-02 (J. Fletcher); Calgary, 9 ♂♂, v-29-14 (F.H. Wolley Dod); Elkwater, 1 ♀, vi-15-29 (J.H. Pepper); Fort Fitzgerald, 2 ♂♂, 1 ♀, vi-30-50 (W.G. Helps); Lethbridge, 2 ♂♂, v-29-29 (J.H. Pepper); Manyberries, 1 ♀, vi-4-56 (E.E. Sterns); McMurtry, 2 ♂♂, vi-4-53 (W.J. Grown); Nordegg, 5 ♂♂, 2 ♀♀, vi-13/28-21 (J. McDunnough); Waterton Lakes, 1 ♂, vi-27-29 (J.H. Pepper), 2 ♂♂, 1 ♀, vi-20/27-33 (J. McDunnough), 1 ♂, vi-14-22 (C.H. Young). BRITISH COLUMBIA. Atlin, 2200', 13 ♂♂, 12 ♀♀, v-28/vi-24-55 (B.A. Gibbard & H. Huckel); Clinton, 9 ♂♂, 2 ♀♀, vi-10-38 (G.S. Walley); Fairview, 1 ♂, v-6-36 (A.N. Gartrell); Fort Nelson, 1 ♂, vi-10-48 (W.R. Mason); Fort St. John, 1 ♂, vi-12-27 (P.N. Vroom); Garnett Vy., Summerland, 1 ♂, v-13-33 (A.N. Gartrell); Grand Forks, 1 ♀, v-26-37 (J.K. Jacob); Hedley, 6 ♂♂, vii-21-33 (C.B. Garrett); Hedley, Nickel Plate, 5000', 6 ♂♂, 1 ♀, vii-16/17-53 (McGillis & Martin); Hope Mts., 6000', 1 ♂, viii-2-32 (A.N. Gartrell); Jesmond, 1 ♀, vii-17-37 (J.K. Jacob); Kamloops, 4 ♂♂, 3 ♀♀, vi-7-37 (J.K. Jacob); Kamloops, Mt. Lolo, 5 ♂♂, 4 ♀♀, v-31/vi-2-38 (G.S. Walley); Merritt,

3 ♂♂, v-15-37 (J.K. Jacob); Midway, 2 ♂♂, 1 ♀, v-27-37 (J.K. Jacob); Okanagan Falls, 1 ♂, v-15-53 (D.F. Hardwick); Oliver, 1 ♂, v-20-59 (R. Madge); Osoyoos, 2000-2500', 3 ♂♂, v-13-53 (Hardwick & McGillis), 6 ♂♂, 1 ♀, v-21-53 (J. Martin), 1 ♀, vii-1-53 (McGillis), 1 ♀, vi-8-53, 1 ♂, vii-3-53 (D.F. Hardwick), 3 ♂♂, 4 ♀♀, v-19-38 (J.K. Jacob); Osoyoos, Anarchist Mt., 2 ♀♀, v-8-36 (A.N. Gartrell); Pavilion Lake, 2 ♂♂, 1 ♀, vi-6-38 (J.K. Jacob); Seton Lake, 1 ♂, vii-29-33 (J. McDunnough); Shingle Crk., Penticton, 11 ♂♂, 8 ♀♀, vi-5-33 (J. McDunnough); Victoria, 1 ♂, iv-5-1885, 1 ♀, v-26-1882, 1 ♂, v-11-04 (No Collector), 1 ♀, vi-3-03 (G.W. Taylor). MANITOBA. Gillam, 15 ♂♂, 9 ♀♀, vi-16/vii-7-50 (J.F. McAlpine); Riding Mts., 1 ♂, vi-9-37 (W.J. Brown), 36 ♂♂, 5 ♀♀ (Brown & J. McDunnough). NORTHWEST TERRITORIES. Fort Smith, 1 ♂, v-30-51, 14 ♂♂, 10 ♀♀, vi-2/17-50 (J.B. Wallis); Hay River, 1 ♂, vi-14-51 (P.R. Ehrlich); Norman Wells, 7 ♂♂, 4 ♀♀, vi-10/vii-11-49 (S.D. Hicks), 1 ♀, vii-4-49 (W.R.M. Mason); Yellowknife, 7 oo, 4 oo, vi-13/30-49 (E.F. Cashman & R.R. Hall). ONTARIO. Beardmore, 15 mi. E., 2 ♂♂, vi-1-58 (P.D. Syme); Fort Williams, 2 ♀♀, vi-?-64 (No Collector). SASKATCHEWAN. Cut Knife, Atton's Lake, 4 ♂♂, 2 ♀♀, v-29-40 (A.R. Brooks); Cypress Hills, 1 ♀, vi-19-39 (A.R. Brooks); Harlan, 1 ♂, 2 ♀♀, v-26-40, 1 ♂, v-24-41, 2 ♂♂, 2 ♀♀, v-12/14-47 (P.F. Bruggemann); Nipawm Nat. For., 1 ♂, v-25-42 (F.H. Chermock). YUKON TERRITORY. Dawson, 1 ♂, 1 ♀, vi-10/21-49 (W.W. Judd); Dawson, 1500-2000', 11 ♂♂, 12 ♀♀, vi-8/vii-1-49 (P.F. Bruggemann); Pelly River, below Hook River, 1 ♀, vii-5-07 (J. Keele); Rampart House, 1 ♀, vi-8-51 (C.C. Loan); Ross River, 132° 30', 61° 56', 3000', 1 ♂, 1 ♀, vi-21-60 (J.E.H. Martin); Whitehorse, 1 ♂, vii-4-48 (W.R. Mason), 3 ♂♂, 1 ♀, vi-1-49 (P.F. Bruggemann), 1 ♂, vi-10-49 (D.A. Mitchell), 2 ♀♀, vi-6/21-49 (D.L. Watson), 1 ♂, 1 ♀, ?-?-21 (E.P. Hawes).

UNITED STATES. - ALASKA. Big Delta, 4 ♂♂, v-28/vi-18-51 (Mason & McGillis); Moose Pass, Kenai Peninsula, 3 ♂♂, 2 ♀♀, vi-20/vii-2-51 (W.J. Brown); Richard Hwy., Mile 270, 3 ♂♂, vi-4-65 (Mason & McGillis); Richard Hwy., Mile 275, 3 ♂♂, 1 ♀, vi-6-51 (Mason & McGillis).

Euchloe creusa

CANADA. - ALBERTA. Banff, 1 ♂, vii-7-02 (J. Fletcher), 1 ♀, vii-1-07, 1 ♀, vi-25-08 (F.H. Wolley Dod); Banff Nat. Park, 3 ♂♂, 2 ♀♀, vii-9-55 (Brown, McGillis & Shewell); Canyon Crk., 4000', 1 ♀, vii-1-65 (J.R.H.); Hillcrest, 1 ♂, 1 ♀, vi-20-20 (No Collector); Laggan, 1 ♂, No Date (T.E. Bean); Laggan, Mt. Pinair, 7000', 1 ♂, 1 ♀, vii-17-07 (F.H. Wolley Dod); Moraine Lake, 1 ♂, vii-20-38 (G.S. Walley); Nordegg, 3 ♂♂, 3 ♀♀, vi-10/22-21 (J. McDunnough); Sunwapta Pass, 6600', Banff-Jasper Hwy., 1 ♂, vii-9-55 (R. Coyles); Waterton Lakes Park, 1 ♂, vii-2-22 (C.H. Young). BRITISH COLUMBIA. Atlin, 2200', 5 ♂♂, vi-6/26-55 (R.A. Gibbard & H. Huckel); Atlin, 4000', 1 ♂, vii-26-55 (H.J. Huckel); Golden, 1 ♀, v-29-64 (J.R.H.); Kootenay Park, Vermillion River, base of Mt. Gray, 4800', 1 ♀, vii-15-55 (R. Coyles); Summit Lake, Mile 392, Alaska Hwy., 7 ♀♀, vi-20/vii-8-59 (R.E. Leech & E.E. MacDougall). NORTHWEST TERRITORIES. Cameron Bay, Great Bear Lake, 2 ♂♂, 1 ♀, vii-3-37 (T.N. Freeman); Fort Reliance, Great Slave Lake Region, 1 ♀, vii-6-24 (J. Russell); Great Slave Lake Region, 1 ♂, vi-10-22 (J. Russell); Norman Wells, 4 ♂♂, 1 ♀, vi-9/15-49 (W.R.M. Mason); Reindeer Depot, MacKenzie Delta, 11 oo, 3 oo, vii-1/12-48 (W.J. Brown & J.R. Vockeroth); Saw Mill Bay, 10 ♂♂, vi-18/21-48 (D.F. Hardwick); Yellowknife, 1 ♀, vi-18-49 (E.F. Cashman). YUKON TERRITORY. Aklavik, 1 ♀, vi-16-53 (C.D. Bird);

Old Crow, 1 ♂, vii-2-51 (C.C. Loan); Rampart House, 8 ♂♂, 1 ♀, v-31/vi-31-51 (C.C. Loan & J.E.H. Martin); Sheldon Lake, 131° 37', 62° 54', 3500', 1 ♂, vii-7-60 (J.E.H. Martin); Whitehorse, 2300', 1 ♂, vi-4-49 (P.F. Bruggemann).

UNITED STATES. - ALASKA. Anchorage, 2 ♂♂, vi-5-51 (R.S. Bigelow); Kenai Peninsula, Moose Pass, 2 ♂♂, vi-20/vii-2-51 (W.J. Brown).

Euchloe hyantis

CANADA. - BRITISH COLUMBIA. Garnett Vy., Summerland, 3 ♂♂, 5 ♀♀, v-1/5-33 (A.N. Gartrell); Lillooet, 1 ♂, v-?-27 (A.W. Phair); Okanagan Falls, 2000', 3 ♂♂, v-9/15-53 (D.F. Hardwick); Oliver, 7 ♂♂, 4 ♀♀, iv-22/v-7-23 (C.D. Garrett), 3 ♂♂, 5 ♀♀, iv-22-33 (A.N. Gartrell), 1 ♀, v-16-38 (J.K. Jacob); Osoyoos, 2500', 3 ♂♂, 1 ♀, v-13-53 (D.F. Hardwick & J.R. McGillis); Osoyoos, Anarchist Mt., 1 ♀, v-7-36 (A.N. Gartrell); Penticton, 2 ♀♀, iv-20/26-31 (A.N. Gartrell); Summerland, 1 ♀, iv-20-31 (A.N. Gartrell).

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NOTES AND RECORDS ON
SPECIES IN THE GENERA *POLIA*
OCHSENHEIMER AND *EUXOA* HUBNER
FROM THE WESTERN UNITED STATES
(LEPIDOPTERA: NOCTUIDAE)

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THE MAJORITY OF THE SPECIES considered here represent California records, and "California" has been omitted after the county when this is the case. One species is also new to Nevada and where specimens are from another state, the state is indicated. The specimens cited in this paper are contained in the Bauer-Buckett Collection, Davis; the collection of the California Department of Agriculture, Sacramento; Entomology collection, University of California, Davis. In each species, both male and female genitalic preparations were made.

***Polia lilacina* (Harvey)**

No published records of *Polia lilacina* (Harvey) have included California. Holland (1903) reports distribution in New Mexico, and Crumb (1956) lists Maine, New Hampshire, Connecticut, New York, New Jersey, Pennsylvania, Iowa, North Dakota, Arizona, Nevada, Utah, Colorado, Oregon, Washington, Montana and all the adjacent Provinces of Canada. *P. lilacina* was originally described from Brewster, New York.

A specimen was received from Bishop, Inyo County, 3 August 1960 (R.P. Allen) and was found to be conspecific with *lilacina*. A male and a female, color form *illabefacta* (Morrison), were collected at Fort Dick, Del Norte County, 3 August and 3 September 1962 (J. W. Anderson) respectively. The maculation of this color form is less clearly defined than in *lilacina* and was, for this reason, considered a separate species for some time. The primaries in this form are suffused with lilac-brown and, thus, are somewhat obscured although maculation is more clearly defined in the male.

This well marked species might be confused with *P. liquida* Grote, or *P. meodana* (Smith), both of which possess a broader subterminal space on the primaries than does *lilacina*. Also, the subterminal line on the primaries of this species is not jagged and irregular, but smooth, lacking the outward "W" mark so prominently exhibited in *liquida* and *meodana*.

Another closely related species is *P. rugosa* (Morrison), which possesses an ash-grey pubescence covering the head, thorax, and abdomen. A dark brown pubescence of the same areas and more contrast in the markings readily separate *lilacina* from *rugosa*. Greatest length of forewing in the male is 15 mm; of the female, 16 mm.

***Polia liquida* (Grote)**

Polia liquida Grote occurs in the northern coast ranges of the western United States, extending northward into British Columbia and eastward into Alberta in Canada; in the United States, it extends eastward into Idaho and Montana. Hampson (1905) and Draudt (in Seitz, 1923) also list *P. liquida* in Colorado.

A male and a female were collected four miles east of Point Arena, Mendocino County, 5 July 1958 (W. R. Bauer and J. S. Buckett). Another pair of specimens was collected in the same locality on 10 April 1959, by the same collectors.

Within this group, *P. liquida* may be confused with *P. meodana* (Smith). Smith states, "The species (*meodana*) has been confused with *liquida* Grt., which is a much more contrastingly mottled form occurring in Washington . . . and as figured by Hampson, has narrower, more pointed primaries . . .". The characteristics Smith observed in his specimens remain constant in both species.

Greatest expanse of the forewing in the male is 15 mm; of the female 16-17 mm.

***Polia nevadae* (Grote)**

In the past few years, specimens of the rare *Polia nevadae* (Grote) have been collected in fair abundance. Previous to 1960, this species was little known and poorly represented, if not entirely lacking in most large collections. Forbes (1954) records the "race" *canadensis* Smith, which is a lighter more obscurely marked form of *nevadae*, from "New Brunswick to Mattagami River, Ontario, to Manitoba and Alberta, south to Maine and Franklin County, New York." I have not studied the types these names represent, but as Forbes is a lumpner by most standards, and yet considered *canadensis* to be a separate race, there is reason to question the conspecificity of the forms.

P. nevadae is a mottled brown, the basal area being orange-brown above basal dash, otherwise basal and transverse areas darker than subterminal area; a prominent cream colored "W" mark can be seen on subterminal line; secondaries fuscous. *P. nevadae* is quite a distinct species, its closest relative being *P. atlantica* (Grote). The California specimens of *nevadae* can not be too easily confused with *atlantica*, as *nevadae* is larger and darker. The Colorado specimens of *nevadae* are identical with, and conspecific with specimens taken near the type locality. Forbes (op. cit.) states of *atlantica* "a pale race in Manitoba to Utah, often mistaken for *nevadae*." Therefore, in specimens taken from the Great Plains region, there is reason for due caution in assigning a name to the collected specimens believed to be either *nevadae* or *atlantica*.

The author has examined specimens from California and Colorado, the majority being from Johnsville, Plumas County, California, collected by Mrs. Helena Pini. Greatest expanse of forewing 17-19 mm. *P. nevadae* was originally described from the Sierra Nevada, California, Henery Edwards No. 4582.

***Polia pulverulenta* (Smith)**

Until recently, *Polia pulverulenta* (Smith) has not been recorded west of the Rockies. In general, it is northeastern in distribution. Its previously known distribution was the New England States and adjacent parts of Canada, westward to Vancouver Island, British Columbia. Crumb (1965) lists Colorado and Washington also.

This species is dark ash-grey brown, perhaps its most distinguishing characteristic being a contrastingly large yellow lunule in the tornus region of the primaries. Other California species most likely to be confused with *pulverulenta* are: 1) *P. quadrata* (Smith), which is the same size or slightly larger, dark brown in color and lacking the prominent yellow lunule in the tornus region of the primaries; and 2) *P. assimilis* (Morrison), also closely related to *quadrata* but larger. Hampson (1903) synonymized *pulverulenta* under *assimilis* but work of later authors proved them to be separate species.

Four specimens of *pulverulenta* were collected at the University of California Sagehen Creek Project, four miles north of Hobart Mills, Nevada County, 21 June through 5 July 1962 by M. E. Irwin. One male is in the collection of the University of California, Davis. Greatest length of forewing in both sexes is 14 mm-16 mm.

***Polia lutra glaucopsis* Hampson**

Apparently, *Polia lutra glaucopsis* Hampson is seldom recorded from California, or from other western states. In the past year, two California collections and one Oregon collection were re-recorded. Two males were collected at Fort Dick, Del Norte County, 16 and 30 April 1963, by J. W. Anderson, and one female was collected 5 miles northwest of Corvallis, Oregon, 30 June 1962, by A. N. McFarland.

This subspecies was first discovered inhabiting Vancouver Island, British Columbia, 2 females composing the type series. *P. lutra glaucopsis* was originally described as a subspecies of *P. lubens* (Grote), but work of later authors prove *lutra* (Gueene) and *lubens* to be conspecific, *lutra* being the older of the two names.

This *Polia* is rather distinct and can be recognized by the contrastingly light brown inner marginal half of the basal area accompanied by its whitish tornus area and lilac subterminal area. The greatest expanse of the forewing varies slightly in different specimens, the male being 18 mm, the female 20 mm. The female of *lutra lutra* is slightly larger, with a forewing expanse of up to 22 mm.

Barnes and Benjamin (1927) found "... no good character to sort *glaucopsis*, which is only western *lubens*, from typical *lubens*. Western specimens are often darker in color than some eastern specimens, but the character does not hold for any series." The fact that *glaucopsis* is darker in coloration, accompanied with its more obscure markings and its smaller size, will help to superficially distinguish it from the nominate subspecies. McDunnough (1938) considers *glaucopsis* as a subspecies of *lutra*, but future work will probably prove our western subspecies to be nothing more than a slight variant.

***Euxoa extranea* (Smith)**

Heretofore, *Euxoa extranea* (Smith) has not been recorded in California. With better collecting methods and increasingly larger samples, *extranea* is now collected in large numbers, enabling better evaluation of its specific variation.

California specimens of *extranea* differ slightly from typical material in that the transverse anterior line of the primaries is inwardly shaded and both the transverse posterior line and the subterminal line are outwardly shaded with bands of cream-colored scales. These shadings give the appearance of a lighter ground color than that found in more northern material. This differentiation might be confusing if only a limited number of

specimens are available. Both sexes have dusky brown hind wings rather than "yellow fuscous", as stated in the original description. Originally, *extranea* was described from a single female collected in Montana, and perhaps with further study, the California specimens will prove to be of subspecific merit.

In specimens of both sexes of *extranea* determined by McDunnough (April, 1951, McD. No. 1144 Bauer-Buckett Collection), the ordinary crosslines of the primaries are black with no shadings of cream-colored scales. These specimens were collected at Mount Hood, Oregon, 17 August 1939, 6,000 foot elevation (E. C. Johnston). In a series of over thirty specimens from eight miles southwest of Johnsville, Plumas County, 11 August 1961 (W. R. Bauer and J. S. Buckett), the maculation of the primaries is quite consistently that of the lighter form. Another specimen proving to be conspecific with *extranea* is a female collected at Leavitt Creek, Mono County, 8,000 foot elevation, 10 August 1960 (A. S. Menke). In this specimen, the ordinary lines are as in typical *extranea*. Another specimen from Hornbrook, Siskiyou County, 6 August 1961, is also typical *extranea*.

One female is deposited in the collection of the University of California, Davis. Greatest length of forewing in both sexes is 18 mm.

***Euxoa vertesta* (Smith)**

Euxoa vertesta (Smith), a pale luteous species, was originally described from Stockton, Utah. *E. vertesta* is on the wing in September and October over most of its range; however, specimens have been collected from California in October only. The available literature cites Utah as the only state in which this species occurs. The author has before him twenty-six specimens of both sexes from California, Nevada, and Utah. The California series consists of six males and four females from Olancho, Inyo County, 11 October 1962 (R. P. Allen). The Nevada series consists of one male and two females from Palisade, Eureka County, 4 September 1962 (T. R. Haig). The Utah series consists of two males, one from Dividend, 6-17 September by the same collector.

E. vertesta may be confused with *citricolor* (Grote); however, *vertesta* is characterized by its pale luteous coloration and weakly defined reniform on the dorsal surface of the primaries. The primaries of *citricolor* are light lemon yellow and the reniform is more strongly defined. Both species possess white secondaries and a white abdomen. Both species are found over much of

the same range . . . *vertesta* from Utah westward into California and *citricolor* from Colorado and Arizona westward into California and northward into Washington.

Greatest length of the forewing in both sexes is 15 mm. in *vertesta*.

***Euxoa edictalis* (Smith)**

Euxoa edictalis (Smith) is typically of the Rocky Mountain region in the United States, and extends westward through Canada to British Columbia (Kaslo). Apparently, this species has not been previously recorded from California, thus making this large series before me from Mono County the first published record.

E. edictalis occurs in the White Mountains, Mono County, and can be collected quite abundantly in June at higher elevations. In 1962, and again in 1963, Mr. Paul Mannis and Mr. David Mathais of the White Mountain Research Station, Mono County, (elevation 10,150 feet), have ardently collected many species of which *edictalis* was one.

Through the cooperation of Dr. David F. Hardwick, Canadian National Collection, Ottawa, the author received specimens of *edictalis* from both Colorado and from Kaslo, British Columbia. From these specimens, close examination was made as well as genitalic mounts of both sexes. This study proved the White Mountain specimens to be very close to *edictalis* but there are minor differences throughout.

E. edictalis is quite characteristic and can be confused with no described species thus far. It is characterized by its deep olive, grey-brown ground color of the primaries, the normal markings being deep brown or black; the antennae of the male are bi-pectinate; the thorax is very robust due to the great amount of vestiture.

The greatest length of the forewing in the male is 16 mm; in the female, it is 17 mm.

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PLATE 1

Top row, left, male, *Polia lilacina* (Harvey), Bishop, Inyo County, California, 3 August 1960 (R. P. Allen); top row, right, male, *P. lilacina illabefacta* (Morrison), Fort Dick, Del Norte County, California, 25 June 1963 (J. W. Anderson); second row, left, male, *P. liquida* (Grote), Fort Dick, Del Norte County, California, 21 May 1963 (J. W. A.); second row, right, male, *P. meodana* (Smith), Convict Creek, Mono County, California, 30 June 1963 (M. G. Tunzi); third row, left, female *P. rugosa* (Morrison), Ashland, Maine, 10 July 1945; third row, right, male, *P. nevadae* (Grote), Johnsville, Plumas County, California, 7 June 1963 (H. J. Pini); bottom row, left, female, *P. pulverulenta* (Smith), Sagehen Creek, near Hobart Mills, Nevada County, California, 21 June 1962 (M. E. Irwin); bottom row, right, female, *P. assimilis* (Morrison), Lake Katherine, Oneida County, Wisconsin (H. M. Bower).

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PLATE 2

Top row, left, male, *Polia lutra glacopis* Hampson, Fort Dick, Del Norte County, California, 16 May 1963 (J. W. A.); top row, right, female, *P. quadrata* (Smith), Nelson Creek Road, 12 miles west Johnsville, Plumas County, California, 12 June 1961 (W. R. Bauer & J. S. Buckett); second row, left, female, *Euxoa extranea* (Smith), Mount Hood, Oregon, 17 August 1939, 6,000 ft. elevation (E. C. Johnston); second row, right, male, *E. extranea* (Smith)?, 8 miles southwest Johnsville, Plumas County, California, 12 August 1961 (W. R. B. & J. S. B.); third row, left, female, *E. citricolor* (Grate), 50 miles south Wells, Elko County, Nevada, 10 Sept. 1959 (T. R. Haig); third row, right, female, *E. vertesta* (Smith), Olancha, Inyo County, California, 11 October 1962 (R. P. A.); fourth row, left, male, *E. edictalis* (Smith), Crooked Creek, White Mountains, Mono County, California, 10,150 ft. elevation 26 June 1962 (J. S. B. & G. M. Trenam); fourth row, right, female, *E. edictalis* (Smith), same data as preceding.

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VARIATION IN COLOR AND MACULATION IN A POPULATION OF *NEMORIA PULCHERRIMA*

FROM THE SIERRA NEVADA OF CALIFORNIA
(LEPIDOPTERA: GEOMETRIDAE)

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IT IS OUR PRESENT INTENTION to demonstrate the extreme variation exhibited by a population of the geometrid, *Nemoria pulcherrima* (Barnes and McDunnough), one of the greens from Auburn, California. The specimens concerned were all collected in the spring of 1967 on the rim of the American River Canyon. The specimens were attracted to incandescent white light in front of a white reflective surface from an area of mixed vegetation characteristic of upper Sonoran-transition zone localities. The trees present were scattered individuals of Blue Oak (*Quercus douglasii*), Black Oak (*Quercus kelloggii*), Interior Live Oak (*Quercus wislizenii*), Digger Pine (*Pinus sabiniana*), and Ponderosa Pine (*Pinus ponderosa*). Undergrowth included varied herbaceous vegetation and shrubs, the latter consisting chiefly of Buckeye (*Aesculus californica*), Toyon (*Heteromeles arbutifolia*), and Manzanita (*Arctostaphylos* spp.).

The evenings on which the largest series were collected, February 10 and 17, were fairly warm for that season and were quite dark being one day after the new moon and the day of the first quarter, respectively. Most moths came to the light between the hours of 8:30 and 10:30 P.M., although some specimens were captured as late as 11:30 or 12 P.M. None of the

specimens were reared; but it seems probable that the host plant is oak as it was found to be in southern California by Comstock and Dammers (1937). The same host plant is cited for *pulcherrima* by Comstock (1960). Whether or not he was referring to his rearing of "*naidaria*" or whether he conducted additional rearing experiments is unknown at this time.

Both the larva and pupa are described by Comstock and Dammers (1937) under the specific name *Nemoria naidaria* Swett. However, *naidaria* was synonymized under *pulcherrima* by McDunnough (1938), and the condition remains the same today. It might be interesting to note in McDunnough's 1938 list that he cited "McD." as author of *pulcherrima*. As the original description was by Barnes and McDunnough, we have adhered to the original citation, assuming the "McD." to be an accident of some kind.

As can be seen by the type male in the Contributions . . . by Barnes and McDunnough (1916 vol. 3, pl. 2, fig. 10), this specimen most closely resembles our specimen which is the left one, second row from the bottom on the colored plate. In recent years a reddish form has been noticed in certain populations of *pulcherrima*, and in a considerable percentage also. Of the specimens examined from the 1967 collection at Auburn, one third of the population was of the red form. Of the red specimens only 10 per cent lacked the dark transverse lines of both the primaries and secondaries; however, the black discal dots seen in the upper left specimen (colored plate) were found to be prominent. In the green specimens of the population, 60 per cent of the specimens possessed prominent black transverse lines, and 24 per cent possessed faint black transverse lines, making up a total of 85 per cent of the green phenotypic portion of the population. The discal dots were always found to a greater or lesser degree of prominence. In the coast range populations of central California, one may encounter specimens in which the discal dots may be entirely lacking, and seldom does one collect specimens possessing the transverse lines.

It was suspected that the coast range populations and the Sierran populations might represent two distinct entities specifically, but there appears to be inadequate evidence at this time to warrant the erection of a new name. Future revisionary work and additional biological studies may reveal intricate characters by which one may be able to distinguish the Sierran and coastal populations at the specific level.



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A NEW SUBSPECIES OF *CALLOPHRYS*
(*CALLOPHRYS*) *DUMETORUM* FROM
WASHINGTON AND OREGON
(Lycaenidae)

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CALLOPHRYS (*CALLOPHRYS* *DUMETORUM* Bdv., along with other members of this subgenus, is characterized by the green color and the presence (or absence) and arrangement of white maculations on the ventral surfaces of the wings. More than 500 specimens examined by the author indicate that this species ranges from British Columbia to Baja California Norte. The southernmost extension of this range, Los Angeles and San Diego counties in California, and Baja California is supposedly inhabited by *C. dumetorum perplexa* Barnes & Benjamin. Current work on this subgenus by the author (in press under another title), however, suggests that this subspecies is consubspecific with typical *C. dumetorum* which occurs as far north as southern Oregon. Unfortunately, problems exist concerning the identification and classification of members composing the subgenus *Callophrys* in that scale color on the ventral surfaces varies from one population to another within a single subspecies. Life histories of several populations of *C. dumetorum* were examined to determine whether those populations in the Pacific Northwest discussed by Clench (1963) are biologically distinct or in fact variant populations of the typical form.

The biology of one population of typical *Callophrys dumetorum* studied by the author at Antioch, Contra Costa County, California in April, 1967 was observed on a common leguminous shrub, *Lotus scoparius*. This plant, common throughout the Coast Ranges of California, is a known foodplant of this species in southern California and females are known to oviposit on *Eriogonum fasciculatum foliolosum* in the deserts (Coolidge, 1924).



Fig. 1 — Immature stages of *Callophrys dumetorum* (Bdv.) — mature larvae, prepupa and pupa (V-18-1967) from *Lotus scoparius* Ottley. (Brannan Island State Park, Sacramento County, California). (Photo courtesy of P. E. Turner, Jr.).

Fig. 2 — Mature, fourth instar larvae of *Callophrys dumetorum oregonensis* Gorelick on *Lotus crassifolius*. (Benth.) Green. (1964) (Falls City-Valsetz Road area, Polk County, Oregon). (Photo courtesy of D. V. McCorkle).

In Washington and Oregon, available hostplant species differ considerably. Newcomer (1965) lists *Eriogonum heracleoides*, *E. compositum* and *E. elatum* as hostplants for *C. dumetorum*, while at Satus Pass, Yakima County, Washington, Dave McCorkle (in correspondence - May, 1967) indicated that *C. dumetorum* oviposits on *Lotus nevadensis*. According to McCorkle (1965), the Polk County (Oregon) population feeds on *Lotus crassifolius*, a common legume of the northern Coast Ranges. In addition, it is interesting to note that specimens examined from Benton County (Oregon) resemble typical *C. dumetorum* found in California whereas several Polk and Yamhill County (Oregon) populations have a phenotype similar to that of the Satus Pass population. Although all of the plant species mentioned above occur in California, they have never been recorded as hostplants for *C. dumetorum* there.

Flight periods as given by Newcomer (1964) for Yakima County, Washington show that the peak flight is in May, at least one month later than the Antioch (California) population as observed by the present author, with many southern California populations often seen as early as February.

A comparison of the larvae from the Antioch population of *C. dumetorum* and a Polk County (Oregon) population indicate that they differ considerably in color and substrate (see photos 1 and 2). On the basis of these life history differences and several adult morphological details distinguishable from over 300 examined specimens of typical *C. dumetorum* from all over California, a name was given to those Washington and northern Oregon populations in the northern Coast Ranges.

***Callophrys dumetorum oregonensis* Gorelick**

ssp. nov.

HOLOTYPE MALE: Costa of forewing 11 mm. from base to apex; outer margin of forewing to CU_2 and slightly indented at A_2 margin of hindwing with shallow crenations, very weakly between Cu_1 and Cu_2 , more pronounced between CU_2 and A_2 as in the typical form; white annuli of antennae 15 (with an incomplete 16th) as seen laterally; palpi dark above, with intermittent white scaling below; facial hairs erect as in typical form; body dark above, pale below; legs with both gray and white scales, appearing annulated along tarsi.

Dorsal surface of forewing a uniform gray rather than gray brown seen in typical form; veins concolorous; stigma light, greatly contrasting with wing; fringes of forewings and hindwings gray basally, becoming white apically.

Ventral surface with light green or yellow green scales reaching posteriorly to Cu_2 ; costa of forewing brown; fringes as on dorsal surface.

Hindwings with green scales present over entire surface; macular band present as two white spots with no apparent inner black scales as soon in many of the paratype specimens; first macule present in cell Sc, the second in cell Cu_2 ; fringes as on forewings.

ALLOTYPE FEMALE: Differing from holotype male as follows:

White antennal annuli 17; dorsal surface uniform golden brown; macular band on forewings present as two extremely faint spots in M_3 and Cu_1 cells, totally absent on hindwings.

Of a total of 55 paratypes examined, nearly all were considerably smaller than the nominate subspecies; the costa of the forewings in the latter is at least 13 mm. in length. The males are gray, with little or no trace of brown, whereas females are golden brown, often with gray scales present along the margins of both the forewings and hindwings. The fringes are always with mixed dark and light scales as seen in typical *C. dumetorum*. The green on the undersides of both sexes varies from light green to grass green, most appearing much paler than the California populations. The maculations on the hindwing undersides, also quite variable in this subspecies, are present as several separated faint spots, three or four closely connected bars, or an incomplete macular band similar to that seen in *C. sheridani* and *C. viridis* specimens. Most specimens examined show the invasion of scales posteriorly to the Cu_2 vein of the forewing as mentioned earlier. Earlier descriptions of *Callophrys* (s. str.) species used the term "fuscous" to define the brown scale shade present; this term has not been used here in order to render a more concise description.

TYPE LOCALITY: Kusshi Creek, 2200', Yakima County, Washington.

TYPE MATERIALS: Thirty males and twenty-seven females as follows:

WASHINGTON. *Klickitat Co.*: Satus Pass, 3000' to summit, ♂, V-4-55 (D. L. Bauer) ♂, ♀, V-18-63, 2 ♂, V-24-63, ♀, VI-18-63, 2 ♀, V-26-64 (all E. J. Newcomer), ♂, 2 ♀, VI-8-63 (D. V. McCorkle). *Yakima Co.*: 3 mi. E. of Fort Simcoe, 3 ♂, V-8-64, ♂, ♀, V-11-64, 4 ♀, V-19-64 (all E. J. Newcomer); Kussli Creek, 2200', 3 ♂, 2 ♀, V-24-63, ♂, ♀, V-13-64, 2 ♂, V-23-64, ♂, V-21-65, ♂, V-9-66 (all E. J. Newcomer), ♂, V-20-62 (R. E. Woodley). *Mason Co.*: Shelton, ♂, ♀, V-23-57, 3 ♂, 2 ♀, V-2-58 (all D. L. Bauer); Stimson Creek, ♂, IV-17-49, ♂, V-7-49 (E. C. Johnston). *Chelan Co.*: Sand Creek, 2 ♀, V-29-57 (D. L. Bauer). *Okanogan Co.*: Black Canyon, ♂, V-4-47 (E. C. Johnston). OREGON. *Clackamas Co.*: near Big Eddy, 960', ♀, V-19-58 (no collector). *Polk Co.*: 4 mi. W. of Falls City, 1500', ♂, V-30-64 (D. V. McCorkle); Falls City-Valsetz Road area, ♂, 3 ♀, V-26-67 (D. V. McCorkle). *Wasco Co.*: 2 mi. SW of Rowena, 525', ♂, VI-6-64 (E. & S. Perkins); 15 mi. SW of the Dalles, 2600', ♂, VI-16-62 (E. & S. Perkins); 7.5 mi. E. of Bear Springs, Hwy. 52 at 3000', ♀, VI-10-56 (O. E. Sette). *Yamhill Co.*: Baker Creek Valley, 300', ♂, ♀, VI-8-30, ♀, VI-27-30 (K. M. Fender). IDAHO. *Adams Co.*: near mouth of Wildhorse River, Wildhorse, ♀, V-12-59 (S. G. Jewett, Jr.).

The type material examined has been distributed as follows: Holotype male and allotype female in the collections of the California Academy of Sciences, San Francisco; two male paratypes in the collection of the California Insect Survey, University of California, Berkeley; one male paratype and one female paratype in the collection of the Los Angeles County Museum; one male paratype in the collection of the Nevada State Museum in Carson City; one male paratype in the collections of the U. S. National Museum, Washington, D. C.; the remaining paratypes are currently being retained in the collections of S. J. Jewett, Jr., D. L. Bauer, and the author.

I wish to extend my sincere thanks to E. J. Newcomer, Yakima, Washington, David V. McCorkle, Monmouth, Oregon, Stan Jewett, Jr., Portland, Oregon, E. Dornfeld, Corvallis, Oregon, and David L. Bauer, Bijou, California for the loan of their specimens without which this study could not have been undertaken.

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NOTE ON DAMAGED SPECIMENS

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IT IS INTERESTING to note the extent to which butterflies may be damaged and yet remain capable of normal flight. This note presents measurements on a few specimens with severe wing damage and discusses these with reference to some of the pertinent literature.

ATTACKS BY BIRDS

There is considerable debate in the literature regarding bird attacks, the interest being in supporting or discounting Batesian mimicry. For example, Wheeler (1935) concludes that attacks on flying butterflies are very rare and that most insectivorous birds are incapable of capturing uninjured butterflies in flight. This is stated to lead to the conclusion that "the current theory of mimicry as applied to the upper wing colors of butterflies is unsound". However, a considerable number (262) eyewitness accounts of bird attacks compiled by Collenette (1935) showed that 17% of the butterflies were captured at rest and 83% in flight. Of course, it is recognized that in-flight attacks are the more conspicuous, so that the only valid conclusion is that in-flight captures are not uncommon.

Collenette (1935) also notes that symmetrical damage, as in specimens 1 and 4 in the figure, strongly indicates a bird attack, probably while the insect was at rest rather than with wings momentarily together in flight. Carpenter (1942) examined 14,000 specimens for beak marks on the wings and concluded that the small percentage of beak-marked specimens evidently attacked at rest (symmetrical damage) militates against the view that butterflies usually are attacked at rest. Therefore, it follows that mimicry on the upper surface *would* be perceived by birds. This conclusion is in disagreement with Wheeler's belief



Fig. 1

All specimens were taken near Morristown, New Jersey and were flying strongly when captured. 1 — *Papilio polyxenes asterius* Stoll, ♀, taken Aug. 6, 1966. 2 — *Papilio troilus* Linnaeus, ♀, taken Aug. 6, 1966. 3 — *Papilio glaucus* Linnaeus, ♂, taken Aug. 30, 1967. 4 — *Limenitis arthemis astyanax* Fabricius, ♂, taken July 30, 1966. 5 — *Papilio troilus* Linnaeus, ♂, taken Aug. 12, 1966. 6 — *Hemaris thysbe*, taken Aug. 7, 1966.

that attacks on flying butterflies are rare but does no more than remove one objection to the theory of upper-surface mimicry. Incidentally, a recent criticism of the common mimicry theory, e.g. the Monarch-Viceroy relationship, is given by Urquhart (1960).

An interesting conclusion by Carpenter (1942) is that attacks by birds upon butterflies are predominantly (about 55% of cases studied) from behind and less often from in front (about 30%) or from the side (about 15%). Specimen 2 in the figure shows what seem to be beak marks on the hind wings, while specimens 3 and 5 show considerable tearing; according to Collentte (1935) the majority of butterflies after being captured by birds show torn wings rather than clear beak marks. However, as Collentte notes, unless the attack is seen, torn wings cannot be ascribed to bird attacks with any degree of confidence.

Thus, specimens 1-5 seem to illustrate two cases of bird attacks from the rear while at rest (specimen 4, which is clipped very cleanly, and specimen 1), one case of bird attack(s) from behind in flight (specimen 2), and two other possible cases of attacks in flight (specimens 3 and 5).

EFFECT OF DAMAGE ON FLIGHT

The wing areas for the specimens in the figure were determined by inking the outline of the wings on clear plastic sheet (0.042 inch thick), cutting along the lines, and weighing the tracings with an analytical balance. The areas for undamaged fore- and hindwings were determined similarly by consulting undamaged specimens. The extents of wing areas remaining then were calculated and are given in Table 1. Since all of specimens 1-5 were flying vigorously and apparently going about their usual activities, a considerable part of the wing area (32% for specimen 1) seems to be expendable, at least when removed largely from the hindwings.

Static loads (weight of insect divided by wing area) have been recorded for various insects; examples (experimentally determined and from the literature) are given in Table 2. The experimental determinations are based on weights of freshly-killed specimens.

Assuming the static load to be about 0.009 g./cm.² for an undamaged *Papilio polyxenes asterius* Stoll female, damage has raised the load to 0.013 g./cm.² for specimen 1, an increase of about 47% (neglecting weight of wing membrane lost).

Table 1

EXTENTS OF DAMAGE FOR SPECIMENS 1-5

Specimen No.	Forewing, P. C. Area Retained			Hindwing, P. C. Area Retained			Total Area, P. C. Retained
	Left	Right	Both	Left	Right	Both	
1	96	83	89	43	50	47	68
2	99	100	100	28	83	56	78
3	94	87	91	64	41	53	72
4	100	100	100	54	59	57	79
5	100	100	100	55	95	75	88

P. C. = per cent

Table 2

STATIC LOADS

Item	Static Load, g./cm. ²	Reference
<u>Papilio glausus</u> Linnaeus (male)	0.0093	
<u>Papilio troilus</u> Linnaeus (male)	0.0081	
<u>Cercyonis pegala</u> Fabricius	0.0063	
<u>Colias eurytheme</u> Boisduval (male)	0.011	
<u>Hemaris thysbe</u>	0.10	
Papilionids and pierids	approx. 0.01	Portier, 1949
Butterflies in general	0.01 - 0.015	Portier and de Rorthays, 1926
<u>Bombus</u> (Bombidae)	0.25	" "
Monoplanes, circa 1926	1.3 - 2.3	" "
Aircraft, circa 1953	7.5 - 40	Chadwick, 1953

The following simple experiments give some idea of the extent of wing loss that can be tolerated and of the relative importance of forewings vs. hindwings.

Hemaris thysbe. — Complete removal of the hindwings (37% of total wing area) had no apparent effect on flight, but removal of the apices of the forewings (comprising about 32% of the forewing area), as shown in the figure (specimen 6), resulted in slanting flight, perhaps 30° from the horizontal, toward the floor.

Limenitis archippus Cramer. — After removal of the apices of the forewings to the extent of 53% of the forewing area (27% of total wing area), a specimen still was capable of level flight for 10 feet. The wingbeats seemed faster, as has been noted for insects when the wing area is reduced (Chadwick, 1953). When the hindwings (49% of total area) were quite removed, another specimen flew well but somewhat erratically. Then, removal of the apices of the same specimen to the extent of 20% of the forewing area caused even more erratic flight, but level flight for 10 feet was achieved. The forewings (51% of total wing area; forewings are 50-56% of the total for the four species of specimens 1-5, incidentally) were quite removed from another specimen. Complete inability to fly resulted, and the insect was unable to rise above an inch from the floor. Thus, level flight is possible using 80% of the forewings when the hindwings are missing, but no flight is possible using 100% of the hindwings when the forewings are absent.

Colias philodice Latreille. — As with the Viceroy, complete removal of the hindwings (51% of total wing area) from a male specimen caused flight to be rather erratic, but the specimen could sustain flight for at least one minute and was able to fly across a 25 foot room and readily direct itself to a small (about 1 ft.²) window.

Papilio glaucus Linnaeus. — To test the effect of unsymmetrical damage, even more extreme than for specimen 5 in the figure, one hind wing (25% of total wing area) was removed from an undamaged female. Flight was not noticeably impaired.

CONCLUSION

In the Lepidoptera, the hindwings are said to associate closely with the forewings to yield a single aerodynamic unit (Chadwick, 1953). However, though the wing area is about equally divided between fore- and hindwings for the butterfly species studied above, the forewings are dominant so that a limited part

of the forewing area seems expendable vs. a major part of the hindwings. Fortunately, attacks by birds tend to come from the rear. Also, unsymmetrical damage can be tolerated, and in-flight bird attacks, perhaps very common, tend to damage the wings on one side more than the other (e.g., specimens 2, 3, and 5 in the figure).

It seems possible that the large wings of some butterflies are a rather neutral factor in regard to survival of bird attacks. That is, butterflies may be more conspicuous to birds than are bees, for example, but an increase in relative frequency of attacks may be balanced by reduced relative frequency of success in that birds tend to peck at the partly-expendable wings (especially the hindwings) and miss the body. It might even be hypothesized that the hindwings of certain species, for example *Papilio troilus* Linnaeus, which are conspicuously marked and tailed, are of survival value in causing birds to peck at the most-expendable part of the insect. Also, in many species the margins (expendable) of both fore- and hindwings often are decorated conspicuously.

This idea, like Batesian mimicry, might be most difficult to demonstrate convincingly. Urquhart (1960) notes that bright white tags applied to the wings of Monarchs seemed to attract the attention of birds. A possible (though perhaps not practical) experiment would be to apply white tags to various parts of the wings of a large number of individuals of a suitable species of butterfly and release these in a roomy aviary along with insectivorous birds. To support the above idea, significantly more specimens with tags on the hindwings and/or margins of the wings should survive (remain in flying condition) than those marked with tags on the inner parts of the forewings. A likely result, of course, is that the birds might not be capable of enough accuracy to strike at the particular part of the wing surface with the tag. This would give survival rates independent of tag position and tend to discount the survival value of conspicuous markings on the more-expendable areas of the wings, at least for the particular bird species involved.

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THE GENERIC, SPECIFIC AND LOWER CATEGORY NAMES OF THE NEARCTIC BUTTERFLIES

PART 7 — The Genus *Dryadula* PADDY McHENRY

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THE SINGLE SPECIES occupying this genus has been shifted from one genus to another since its original description by Linnaeus. In addition to the genus *Dryadula* Michener, it has been included by various authors in *Papilio* Linnaeus, *Cethosia* Fabricius, *Dryas* Hübner, *Colaenis* Hübner and *Agraulis* Bosduval & LeConte.

The spelling of the name *phaetusa* has been unsatisfactorily; Linnaeus, himself, spelled it first as *phaetusa* and later as *phaerusa*. As *phaetusa* has definite priority it should be accepted as the proper spelling. The genera, including this one, comprising the Nearctic subfamily Heliconiinae have an unfortunate history of spelling errors for the specific names.

LIST OF THE GENERIC NAMES USED OR AVAILABLE FOR DRYADULA

DRYADULA Michener.

Type. *phaetusa* (Linnaeus).

DRYADULA MICHENER, 9 Oct. 1942, Amer. Mus. Nov. (1197): 1, no. 6; p. 4; figs. 5 and 10.

Type. *P[apilio]*. *N[ymphalis]*. [*Phaleratus*] *phaetusa*
Linnaeus, 1758, Syst. Nat. (10th. ed.), 1: 478, no. 123.

Type Selection, Michener, 9 Oct. 1942, Amer. Mus. Nov. (1197): 4. He said: "Genotype. - *Papilio phaetusa*
Linnaeus, 1758."

LIST OF SPECIES AND LOWER CATEGORY NAMES USED OR AVAILABLE FOR DRYADULA

1. DRYADULA PHAETUSA (LINNAEUS)
phaetusa (Linnaeus).

1. DRYADULA PHAETUSA (LINNAEUS).

phaetusa, *P[apilio]*. *N[ymphalis]*. [*Phaleratus*] Linnaeus.
1758, Syst. Nat. (10th. ed.), 1: 478, no. 123.

"Habitat in Indiis". No sex, series nor date

data given. The name was given as *phaerusa* by
Linnaeus, 1764, Mus. Lud. Ulr. ([1]): 293, no.

111. The name was also given as *phaerusa* by
Linnaeus, 1767, Syst. Nat. (12th. ed.), 1(2):

780, no. 180, Doubleday, 1847, List Spec. Lepid.
Ins. Coll. Brit. Mus. (2): 65, misspelled the name
as *pherusa* and included it in the genus *Agraulis*.

FIELD STUDIES OF CATOCALA BEHAVIOR

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ALTHOUGH THE CATOCALA have always been popular with collectors, little information concerning their behavior and ecology is available. Some observations on the natural resting habits of adults have been recorded (e.g. Bunker, 1874; French, 1880; Johnson, 1882; Rowley & Berry, 1909; Kettlewell, 1958; and Sargent & Keiper, 1969), but most of these are anecdotal and not of a quantitative nature. The final paper is of particular interest since it includes not only field observations of resting *Catocala*, but also some experimental data which suggests that at least one species of *Catocala* (*Catocala antinympha*), along with several non-*Catocala* species, are capable of selecting backgrounds which match the reflectance of their forewings. Before field data can be used to substantiate these experimental findings, it seems necessary to conduct field observations on a truly quantitative basis. Thus, to determine that moths actually do select the appropriate background in nature, it must be shown that they are not randomly selecting backgrounds, but instead are actively choosing the appropriate ones from among a large number of possible choices. This study presents some preliminary work along these lines.

METHOD

An area of mixed forest was selected in Hampshire County, in central Massachusetts, and the tree composition of the area was determined. The actual number of each tree species, and its percentage of the total forest composition, is presented in Table I.

Each day from July 15 to September 10, 1967, and from July 19 to August 5, 1968, the tree trunks of each of the trees on the experimental plot were searched systematically for resting moths, from ground level to a height of about 20 feet. When a moth was found, it was photographed and extensive notes were taken concerning the moth and its resting place. These notes included information as to the species of tree selected, the resting

Table I. The tree species found on the study plot-their actual and relative abundance.

Tree Species	Actual Number on Plot	Percentage of the total number of trees on the plot
Black Birch <u>Betula lenta</u>	48	33.80
Red Oak <u>Quercus rubra</u>	23	16.20
Red Maple <u>Acer rubrum</u>	21	14.79
White Birch <u>Betula papyrifera</u>	13	9.15
White Oak <u>Quercus alba</u>	10	7.04
White Pine <u>Pinus strobus</u>	9	6.33
Hickories <u>Carya spp.</u>	9	6.33
Sugar Maple <u>Acer saccharum</u>	7	4.93
Hemlock <u>Tsuga canadensis</u>	2	1.41
<hr/>		
Total Number of Trees on study plot	142	

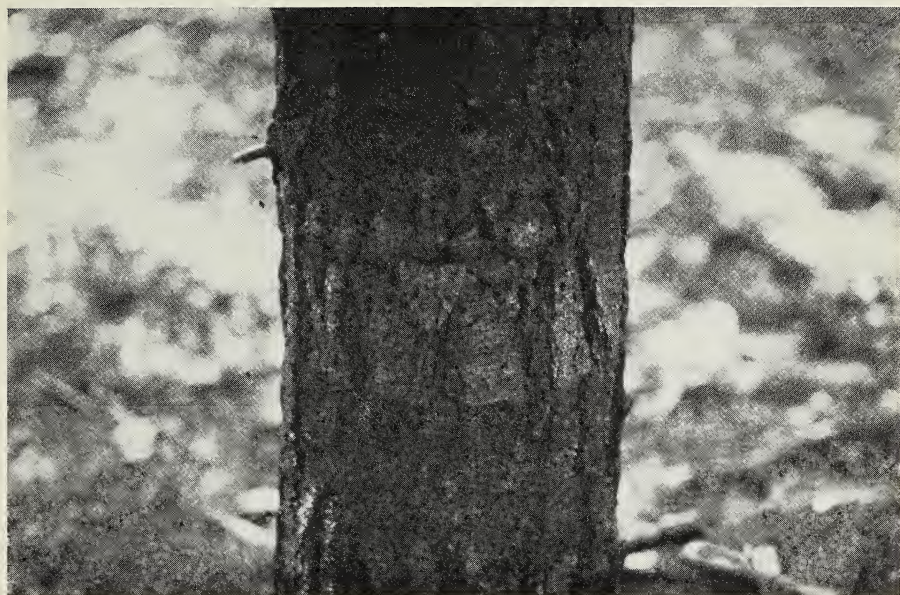


Fig. 1. *Catocala ridua* "head-down" on black birch.



Fig. 2. *Catocala concumbens* "head-down" on white birch.

height of the moth, and the resting attitude ("Head-up" or "Head-down"). The moth was then captured in a glass jar, positive identification was made, and the moth was then released back into the study area.

RESULTS

A total of 70 moths of 14 species were found for which positive identification could be made and complete information gathered. The total number of moths captured on each tree species, and the percentage of this number to the total number of moths captured, is shown in Table II. This data suggests that there may be some selection occurring, for more moths than expected are found on White Birch (*Betula papyrifera*), and possibly Red Oak (*Quercus rubra*), while fewer moths than expected are found on a number of tree species. This suggestion thus requires closer examination of the distribution of each moth species, and these results are included in Table III. Statistical analysis, by Chi Square tests, show that only in the case of *Catocala relict*a is there a significant difference between the expected number of moths on a tree (White Birch) and the observed number of moths. These results are particularly interesting in that *Catocala relict*a is the only species of the 14 studied that is primarily white in color, and thus the only one that would match the color of the bark of White Birch. The other species, having darker forewings, would best match other tree barks, and thus seem not to select particular backgrounds, but only choose any relatively dark barked tree. There may, however, be specific preferences or avoidances among species, but the number of individuals within any one species is so far too small for any consistent trend to be determined.

RESTING ATTITUDE AND RESTING HEIGHT

Two other aspects of behavior have also emerged from this study. First, certain species are consistent in their resting attitude. Of the 14 species studied, only 3 species show a "Head-up" resting attitude while the remainder rest "Head-down". Those species which rest "Head-up" are: *Catocala relict*a, *C. neogama*, and *C. unijuga*. Within any given species, this attitude is consistent; in fact there were no exceptions among any of the species. Thus all 7 of the *C. relict*a studied sat "Head-up", while

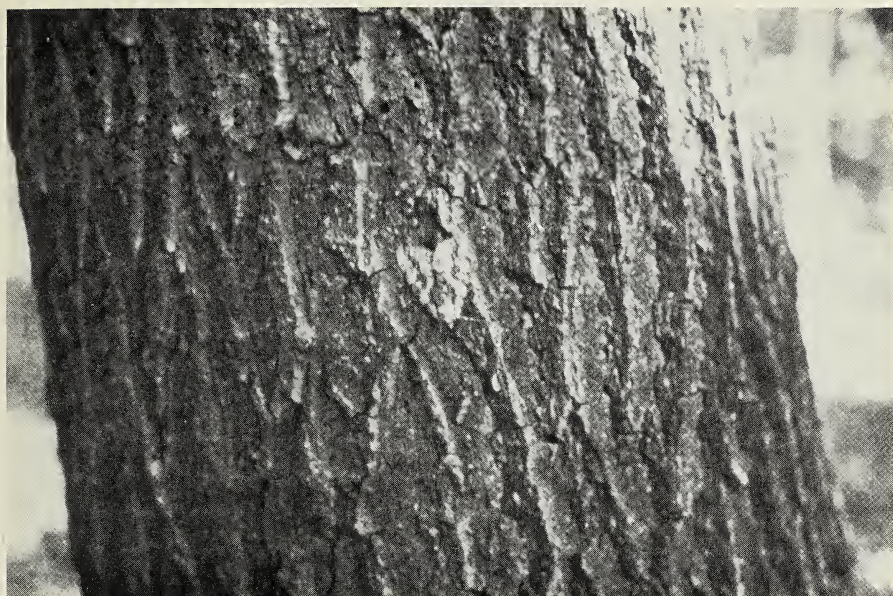


Fig. 3. *Catocala ridua* "head-down" on red maple.



Fig. 4. *Catocala relictata* found at rest — "head-up" on white birch.

Table II. The distribution of the observed moths on the trees
of the study plot.

Tree Species	Number of Moths Captured	Percentage of Total number of Moths Captured
Black Birch (BB)	21	30.00
Red Oak (RO)	13	18.57
Red Maple (RM)	9	12.86
White Birch (WB)	16	22.86
White Oak (WO)	3	4.28
White Pine (WP)	3	4.28
Hickories (H)	2	2.86
Sugar Maple (SM)	3	4.28
Hemlock	0	0.00
<hr/>		
Total number of moths captured on study plot	70	

Significant deviation from chance selection... Analysis by

Chi Square tests, Probability less than 0.01.

all of the individuals of *C. amica* (15), *C. vidua* (13), and *C. gracilis* (12) sat "Head-down". The importance of this resting attitude is now being experimentally studied with respect to possible functions associated with courtship or survival.

The second aspect of behavior noted was the consistency of certain species to select certain resting heights, regardless of the tree species rested upon. These results are shown in Table IV. Species such as *C. ilia* seemed to show a definite preference for resting high up on the trunk. This suggestion is further substantiated by data from released moths. These moths had been captured the previous night at "sugar", kept overnight in an experimental box (involved in other experiments), and released the next morning. Of 12 released *C. ilia*, 10 of the moths selected resting places over 10 feet up on the trunks. On the other hand, *C. vidua* seemed to prefer low resting places. Of the 13 individuals observed in this study, all rested below 9 feet, with 7 of the number resting under 2 feet in height. Once again, the importance of this behavior is not clearly understood, but is being further investigated experimentally.

SUMMARY

A study was made of 3 aspects of *Catocala* behavior by observing resting moths in a woodlot in central Massachusetts during the summers of 1967 and 1968. The first objective was to attempt to determine whether moths selected then rested upon backgrounds which tended to match their forewings. Although the number of individuals in all cases was small, it appeared that *Catocala relictæ*, a moth with primarily white forewings spotted with black to varying degrees, did select White Birch for a resting place.

Secondly, the resting attitude was consistent within any one species, but varied interspecifically. Three of the 14 species studied rested "Head-up", while the remainder sat "Head-down".

Finally, there also seemed to be a preferred resting height for a number of species. Some, such as *Catocala ilia*, generally rested high up on the trunk, while others, such as *Catocala vidua*, rested very low on the trunks.

These results then reveal that a high degree of consistency exists in several aspects of *Catocala* behavior and suggest that further study should be conducted to determine why and how these unique behavioral responses occur.

Table III. The distribution of the most commonly observed species of *Catocala* on the trees of the study plot.

Catocala Species	Tree Species								Total Number of Moths
	<u>BB</u>	<u>RO</u>	<u>RM</u>	<u>WB</u>	<u>WO</u>	<u>WP</u>	<u>H</u>	<u>SM</u>	
<u>C. vidua</u>	2	3	3	4	0	1	0	0	13
<u>C. relictata</u>	0	0	0	6	0	0	1	0	7
<u>C. concumbens</u>	3	1	0	1	0	0	0	0	5
<u>C. gracilis</u>	5	0	1	4	0	1	0	1	12
<u>C. ultronia</u>	2	3	1	0	1	0	0	0	7
<u>C. amica</u>	6	5	1	0	1	1	1	0	15
	13	12	6	15	2	3	2	1	

For abbreviations of tree species, see previous table, Table II.

Significant deviation from chance... Analysis by Chi Square test, Probability less than 0.01.

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 JOHNSON, J. S. 1882. *Catocalas* taken in the vicinity of Frankford, Pennsylvania. *Canad. Entomol.* 14: 59-60.

Table IV. Resting Height of Eight Species of Catocala.

Data Refers only to Observed Resting Moths.

Catocala Species	Resting Height		
	Low(0-3')	Medium (3-9')	High(Above 9')
<u>C. vidua</u>	8	5	0
<u>C. ilia</u>	0	0	3
<u>C. relictata</u>	2	3	2
<u>C. unijuga</u>	0	2	0
<u>C. concumbens</u>	1	3	1
<u>C. gracilis</u>	3	6	2
<u>C. ultronia</u>	0	3	4
<u>C. amica</u>	3	9	3

Denotes those species which rest "Head-up" on the trunk.

(C. neogama also rest "Head-up", but is not included in

the table since only 1 specimen was captured)

- KETTLEWELL, H. B. D. 1958. The importance of the microenvironment to evolutionary trends in the lepidoptera. *The Entomol.* 91: 214-224.
- ROWLEY, R. R. and BERRY, L. 1909. Notes on the study of some Iowa Catocalae. *Entomol. News* 20: 12-18.
- SARGENT, T. D. and KEIPER, R. R. 1969. Behavioral adaptations of cryptic moths. I. Preliminary studies on bark-like species. *J. Lepid. Soc.* (In press).



HABITAT: SPECIFIC TYPE LOCALITY

Plebejus icariodes missionensis H.

SLOPE ON THE WEST SIDE of Twin Peaks, in the City of San Francisco, California (Fig. 1). Approximately eighty percent of the area occupied by this race was obliterated in the 1940's by a housing development. This race was once semi-continuous in distribution with *P. icariodes pheres* Bdv., the distribution of which was tied to that of the blue bush lupine in the sand dunes to the west and north. The perennial prostrate lupine in the foreground (Fig. 2) is the larval host plant.

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LIFE HISTORY NOTES ON *SATYRIUM SYLVINUS DRYOPE* EDWARDS (LYCAENIDAE: THECLINAE)

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THE HAIRSTREAK *Satyrrium sylvinus dryope* Edwards is distributed through the coast ranges from the San Francisco Bay area south to Los Angeles in California. *S. s. dryope* has been considered a species separate from *sylvinus* as late as Clench (1961); however, the maculation and genitalia of the two entities are essentially identical, with the only difference being that *dryope* lacks the tail on the secondaries present in typical *sylvinus* (P. A. Opler, *in litt.*; J. F. Emmel, *in press*). Its foodplant and life history have not been described (Clench, 1961).

The present paper presents a description of the first-instar larva to make this information available for future comparative studies of the larvae of the Theclinae, currently underway by several authorities. The first-instar setal patterns seem to offer the best differentiating characters among the hairstreak larvae and doubtless will prove useful to ascertaining evolutionary relationships when enough life histories are known.

GENERAL BIOLOGY AND FOODPLANT

Satyrrium sylvinus dryope is single-brooded, with adults appearing in late May and June. The specific observations (during 1964-67) in this note are based on the *dryope* populations at the Page Mill Road rock quarry on the Stanford University campus, near Los Altos, Santa Clara County, and were made throughout the flight season as well as at other times of the year.

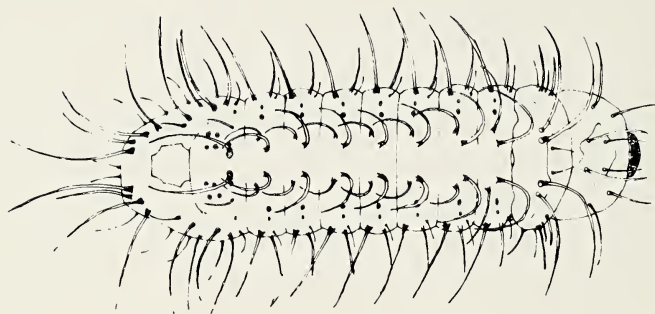
**Fig. 1****Fig. 2**

Fig.1. The first-instar larva of *Satyrium sylvinus dryope* Edwards, dorsal view, with head and prothoracic shield to right and anal shield at left.

Fig. 2. Lateral view of the seventh body segment, showing setal arrangement. Note the supraspiracular round "gland" body.

The host plants are willows (*Salix*). Courtship of the adults takes place around the willows bordering a wet seep. Eggs are laid singly in willow bark crevices, especially at the junctions of branches, in late May to early July. The species overwinters in the egg stage. Larvae hatch the following March. The first two instars feed by cutting a depression in the willow leaf surface epidermis, rather than by cutting into the edge of the leaf.

FIRST INSTAR LARVA

The body is flattened in the usual lycaenid shape. The spine or setal arrangement is as shown in Figures 1 and 2.

The overall ground color is a uniform gray, with small dark-brown elevated "dots" uniformly distributed over the entire body surface. On the head-shield segment, a distinctly-shaped yellowish-green area is outlined in brown. This head-shield area lacks brown dots within it, but four spines protrude forward from its margins.

On the anal-shield segment, there is a differently but distinctly shaped yellowish-green area that is outlined in brown; this area also lacks brown dots and it lacks spines.

The head is a dark brownish black in color and is kept hidden while the larva is feeding.

The spines on all segments of the body and head are translucent, with a dark gray ring at the base of each.

Each body segment has a translucent, dark gray, raised "gland"-like body or organ a short distance above the spiracle. On the anal shield, near the anterior end, there are ten of these dark gray "glands" arranged as shown in Figure 1. Their function, if any, and homology with structures in the supraspiracular position or elsewhere on other lycaenid larvae, remain unknown (e.g., see Clench, 1962).

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- CLENCH, HARRY K., 1962. *Panthiades m-album* (Lycaenidae): Remarks on its early stages and on its occurrence in Pennsylvania. *Journ. Lepid. Soc.*, 15: 226-232.
- EMMEL, J. F., in press. The genus *Satyrium*. In Howe, William H., edit., *The Butterflies of North America*. Doubleday & Co., New York.



HABITAT: GENERAL TYPE LOCALITY

Glaucopsyche lygdamus xerxes Bdv.

Plebejus icariodes pheres Bdv.

SANDY AREA NEAR Lobos Creek, the Presidio, San Francisco, California, the last known area for *G. xerxes* (Fig. 1). The *xerxes* host plant here is *Lotus* sp. (Fig. 2 dried) and the *pheres* host plant is the blue bush lupine, *Lupinus chamisonis* Esch. The last known collections here were made by the author just prior to 1940. There have been no known collections since.

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THE GENERIC, SPECIFIC AND LOWER CATEGORY NAMES OF THE NEARCTIC BUTTERFLIES

PART 8 — *The Genus Agraulis*

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IN PRESENTING THIS GENUS, I have followed, without approval or disapproval, the name used for it by Dr. C. F. Dos Passos (1964, p. 97) since he is the latest author to treat this group. Many previous authors have considered that the type species of *Dione* and *Agraulis* were congeneric and *Dione* has previously enjoyed a popular usage with the species *vanillae* although *Agraulis* had still earlier enjoyed wide acceptance with it.

In addition to *Dione* and *Agraulis*, *vanillae* has been associated by various authors with the genera *Papilio* Linnaeus, *Argynnis* Fabricius, and *Dryas* Hübner.

Fabricius, and *Dryas* Hübner.

The spellings for the specific names in this genus have been relatively free of errors that seem to typify the other genera of the subfamily Heliconiinae for the Nearctic area.

Agraulis 2/6

LIST OF GENERIC NAMES USED OR AVAILABLE FOR AGRAULIS

AGRAULIS Boisduval and LeConte.
Type. vanillae (Linnaeus).
DIONE Hübner
Type. juno (Cramer).

AGRAULIS BOISDUVAL and LECONTE. [1833]¹. Hist. Gén. Icon. Lépid.
Chen, l'Amer. Sept. 1(14): pl. 42; 1(16): 142-145. They
included only "Agraulis Vanillae".
Type. P[apilio]. N[ymphalis]. [Phaleratus] vanillae Linnaeus.
1758. Syst. Nat. (10th. ed.). 1: 482, no. 144.
Type Selection. As Agraulis vanillae was the only species
included in the genus by the authors, it became the
type.

- DIONE HÜBNER, [1819]². Verz. Bekann. Schmett. (2): 31, no. 4
 He included only: "257. Dione Vanillae Linn..." and
 "258. D. Juno Cram..."
 Type. Pap[ilio]. Helicon[ius]. juno Cramer. [1780]³.
 Uitland, Kapellen, 3(24): 175. Described and figured
 earlier without a generic name on page 38, as Fig. B-C
 and on pl. 215, as figs. B-C in Pt. 18, [1779]³.
 Type Selection. Scudder, [8 Apr.] 1875⁴. Proc Amer.
 Acad. Art Sci. 10: 157, no. 343. He said: "Juno may
 be taken as the type."

LIST OF SPECIES AND LOWER CATEGORY NAMES USED OR AVAILABLE
 FOR AGRAULIS

1. AGRAULIS VANILLAE (LINNAEUS).
comstocki (Gunder).
fumosus (Gunder).
hewelettae (Gunder).
incarnata (Riley).
margineapertus (Gunder).
nigrior Michener.
passiflorae (Fabricius).
vanillae (Linnaeus).

1. AGRAULIS VANILLAE (LINNAEUS).

comstocki, Dione vanillae Gunder. 5 Jan. 1925. Ent. News.
 36(1): 5-6, no. 9; pl 1, fig. T. "Data: Holotype
 ♂... Monrovia, Los Angeles County, California, July
 19, 1924."

fumosus, Dione vanillae Gunder. 4 May 1927. Ent. News.
 38(5): 137, no. 9; pl. 2, fig. 9. "Data: Holotype ♀...
 Los Angeles, Los Angeles County, California, Sept.
 15, 1910..."

hewelettae, Dione vanillae incarnata Gunder. 6 Jan. 1930.
 Bull. Brooklyn Ent. Soc. 24(5): 327-328; pl. 31, figs. 7.
 "Data: Holotype ♀... Ontario, Riverside Co., Calif.
 Taken in the summer of 1927..."

incarnata, D[ione]. vanillae N. F. Riley. Sept. 1926.
Entomologist, 59(760): 243-244. "Habitat: Southern
U. S. A. (Illinois, Texas, California and Florida, 9 ♂♂,
7 ♀♀, in B. M.); Mexico (10 ♂♂, 5 ♀♀, including types);
Honduras, 1 ♀; Guatemala, 1 ♂, 2 ♀♀; Nicaragua, 4 ♂♂;
Costa Rica, 3 ♂♂. The type ♂ and ♀ are from near
Durango City, Mexico". No date data given.

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Canad. Ent. 60(7): 163; pl. A, fig. 3. "Data: Holotype
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Amer. Mus. Nov. (1215): 1-2 (in pt.), in no. 2 (in key);
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Florida...". "Paratypes, all from Florida..." Paratypes
from all months of the year except July, December and
January are noted. "The holotype, allotype and a
series of paratypes are in the collection of the
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paratypes are in the collection of Mr. C. F. dos Passos
and Cornell University."

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28 Aug. and 31 Dec.] 1793.⁵ Ent. Syst. 3(1): 60-61,
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Agraulis 6/6

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FOOTNOTES

1. Dos Passos. 1959 [1960]. Jour. Lepid. Soc. 13(4): 212. Gave additional date data for the Hist. Gén. Icon. Lépid. Chen. l'Amer. Sept. by Boisduval and LeConte.
2. Hemming. 1958. Official List Works Approv. Avail Zool. Nomencl. (1): 4. Gave established dates for the Verz. Bekann. Schmett.
3. Hemming 1958. Official List Works Approv. Avail. Zool. Nomencl. (1): 9-10. Gave established dates for certain works of Cramer and Fabricius.
4. A copy of the work among the separates at the Allan Hancock Library (Univ. Sou. Calif.) (ex library, Boston Soc. Nat. Hist.) has the following printed label on the front wrapper: "Library of the Cambridge Entomological Club. Received April 8, 1875, by gift from the author."
5. The title page of Fabricius' Ent. Syst., vol. 3, pt. 1 is qualified by dates on pages [ii] and [488].

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DAYTIME VISION BY THE MOTH, *EXYRA RIDINGSI* (RILEY)¹

VERNON M. KIRK

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Brookings, South Dakota

SPECIMENS OF THE NOCTUID MOTH, *Exyra ridingsi* (Riley), were observed by Jones (1904, 1907) resting within the leaves of the pitcher plant, *Sarracenia flava* L., at Summerville, South Carolina. In an area abounding in plants of this species, he found that when a moth was dislodged from a leaf, it would fly quickly to another leaf, alight outside near the rim, and run in over the edge.

At 10:30 A.M. on 16 June, 1964, I found a specimen of *E. ridingsi* within a leaf of *S. flava* growing in a grassy clearing in a bog about 8 miles inland from Myrtle Beach, South Carolina. When disturbed, the moth darted out of the leaf and straight to the opening of a leaf of another pitcher plant 30 feet away. When again disturbed, the moth darted back to the first plant, but into a different leaf. These 2 plants were the only ones of this species within sight, and there was nothing to block the view between them.

Further examination revealed 2 other specimens of the moth in other leaves of the plants. When disturbed, these moths followed a similar flight pattern in reaching the sanctuary of the plant leaves, and in the 8 or 9 flights observed did not wander more than 6 feet from a straight line between plants. Each flight was completed in less than 3 to 4 seconds, indicating no hesitation by the moths in choosing or locating their refuge.

¹ Identified by Dr. E. L. Todd, USNM.

A careful search of the immediate vicinity revealed no other specimens present, either on the ground or on vegetation. The sky was clear; air movement during the period of flight observation was between 1 and 3 mph and at nearly right angles to the flight path.

It appeared that direct vision was involved, although no further attempt was made to test this possibility. If vision alone were involved, it is remarkable that a moth is able to see and identify, from a distance of 30 feet, a relatively low-growing plant, in bright sunshine.

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NOTICES

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THEORIES ON THE NATURE OF LIFE. Giovanni Blandino, S.J. Philosophical Library, N.Y.

INTRODUCTION TO ZOOLOGY. Theodore H. Savory. Philosophical Library, N.Y.

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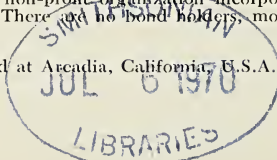
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FIELD WORK ON THE
POPULATION STRUCTURE
OF
OENEIS MELISSA SEMIDEA (SATYRIDAE)
FROM THE
PRESIDENTIAL RANGE, NEW HAMPSHIRE

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*Dartmouth College,
Hanover, New Hampshire*

INTRODUCTION

THE PURPOSE OF THIS STUDY was to assess the extent to which various local populations of *Oeneis melissa semidea* are isolated from one another. This subspecies of a characteristically North American arctic and western alpine species is found throughout the alpine areas of the Presidential Range in New Hampshire, but as has been found with other butterfly species, it seems to have certain localized areas of greatest abundance between which individuals are seldom found. The presence or absence of the butterfly in a given area of the range presumably depends on the presence and quantity of available host food plant, in this case alpine grasses and sedges, and various microclimatic factors such as ground temperature, moisture, and depth of snow cover during the winter.

The study was undertaken with the following two alternative hypotheses as its basis:

1. The population of *Oeneis melissa semidea* is homogeneous over the entire Presidential Range, that is, it is not broken down into local breeding populations, and that a constant flow of individuals and consequently genetic exchange occurs between the various centers of abundance along the range. This situation would tend to result in minimal or at least continuous variation between samples of individuals drawn from selected areas of the range.

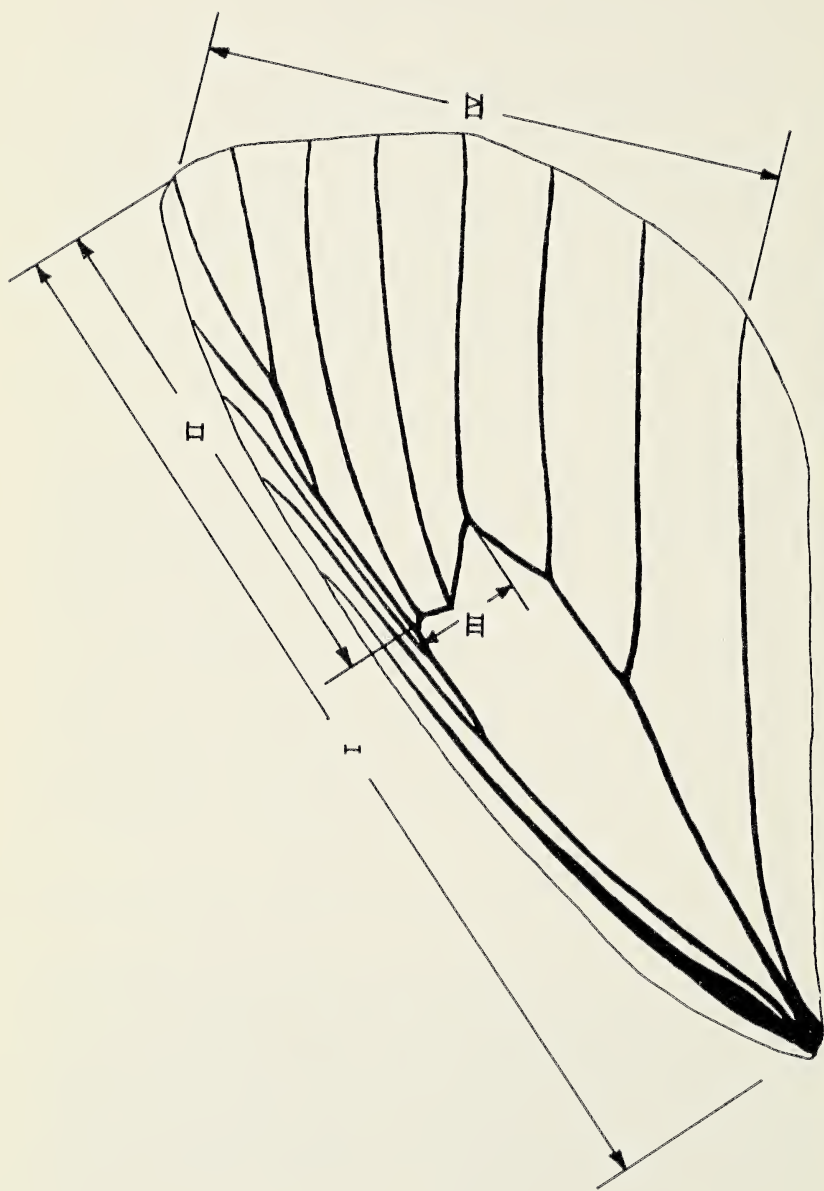


Fig. 1. Diagram of forewing of *Oeneis melissa semidea* showing measurements made in Roman numerals.

2. The population of *Oeneis melissa semidea* is not homogeneous, but rather it is broken down into discrete local breeding populations with little or no exchange of individuals or genetic information between them. This situation would tend to result in greater variation between samples of individuals drawn from selected areas of the range.

It was expected that the true situation for this butterfly lay somewhere between the two hypotheses, depending on certain ecological and environmental factors.

METHODS

The mark-release-recapture method was originally employed to assess the movement of individuals between areas on the range. Individuals were marked with dots of waterproof paint (see Ehrlich, 1960), the position of which identified each individual with a number. In this way, any individual recaptured could be identified as to place of origin, and movements could be detected. In addition, recaptures could be used to estimate the size of the population as a whole, and for individual areas.

Between the dates of 27 June and 7 July, 51 marked individuals were released in the Cowpasture, a rather extensive, relatively flat area at mile 7 of the Mt. Washington auto road. No subsequent recaptures of any of these individuals were made in the Cowpasture or elsewhere. Since difficulty was being encountered in obtaining significant numbers of individuals for marking, and because a number of factors related to the marking technique itself were becoming serious problems, the mark-release-recapture attempts were ended, and pure sampling from the population was begun.

From 8 July until 15 July samples of as large a number of specimens as possible were taken from four selected areas of the Presidentials. From north to south along the range these areas were: Monticello Lawn on Mt. Jefferson (5300-5400 ft.), the area surrounding the Gulf Tanks along the Mt. Washington Cog Railway between the summits of Mt. Washington and Mt. Clay (5700-5900 ft.), the Cowpasture at mile 7 of the Mt. Washington auto road (5700-5800 ft.) and Bigelow Lawn, directly south of the cone of Mt. Washington (5400-5500 ft.). A total of 115 individuals were taken by the author and another 30 were obtained from Donald Lennox of Jefferson, N. H., who collected in the Cowpasture on 8 and 15 July. Of those collected by the author, 13 females were kept alive and later released on

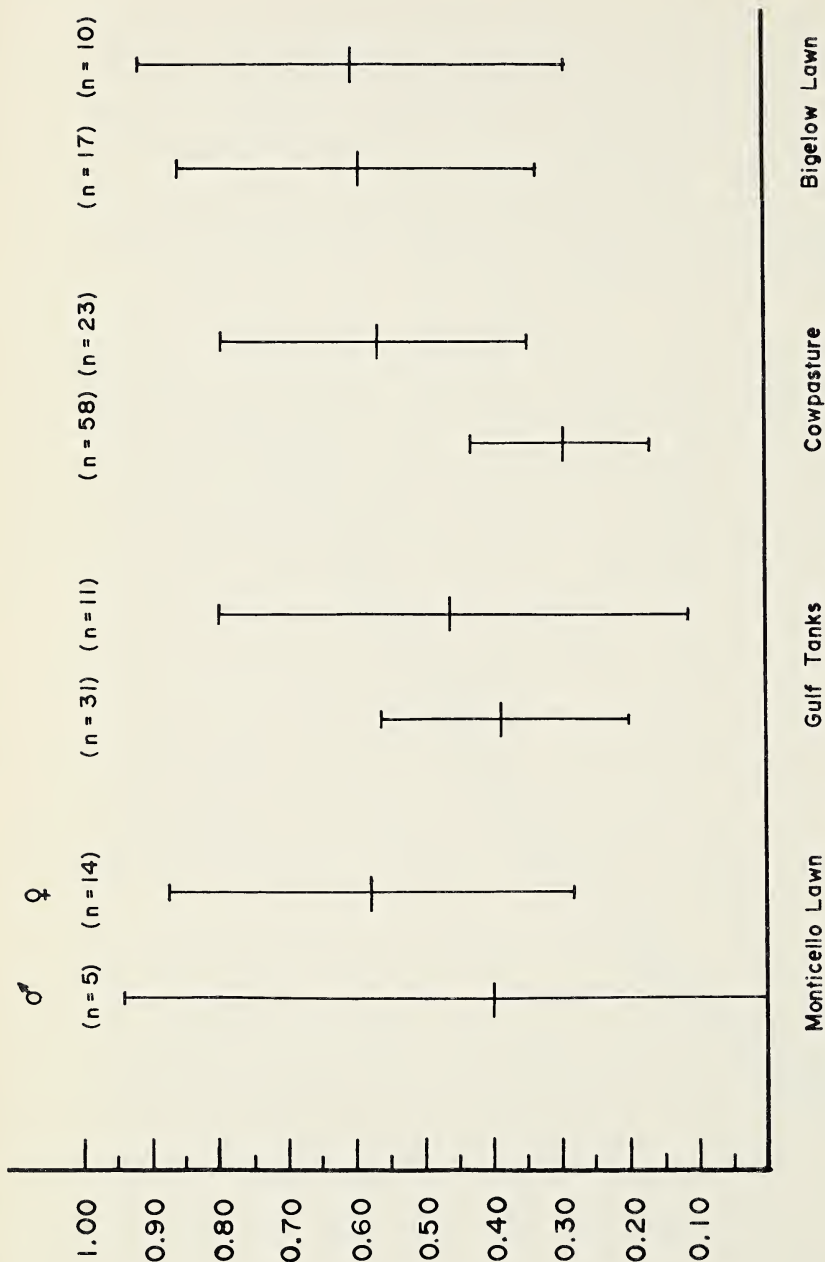


Fig. 2. Frequency of spotting for samples of *Oeneis melissa semidea* from areas of the Presidential Range sampled during the summer of 1969. Observed frequency shown by horizontal dashes; 95% confidence limits shown by vertical lines.

the summit of Mt. Mooselauke at the western edge of the White Mountains. A grand total of 132 individuals were therefore available for study following the initial field work required for the study. Field work ended 2 August.

Up to the present time five characters have been analyzed in an effort to provide evidence of genetic isolation between breeding populations of the butterfly. Males and females have in all cases been treated as separate populations in the analyses because of the lack of any evidence to treat them as the same, and also because the mean values for each character analyzed differ between males and females from a given area, sometimes significantly.

The first character analyzed was the frequency of occurrence of a spot in cell R_5 of the forewing of the butterfly. Determination of the occurrence of a spot was made by visual inspection. In only a small number of cases was the use of a hand lens necessary for determination. The occurrence of a spot was defined as the appearance of a group of scales between veins R_5 and M_1 in the submarginal area of the forewing which were of a darker color (usually black) than the ground color of the wing and which were distinguishable on both the dorsal and ventral surfaces of the wing. This definition eliminated certain color variation appearing most commonly on the forewings of females such as a small light ochreous patch of scales against a darker ground color but without a darker center which is characteristic of eyespots.

The remaining characters were the linear distances between various points on the forewing (see figure 1 for diagram):

I — extreme base of wing to the end of vein R_4 (a standardized indication of the overall length of the wing)

II — base of M_1 to the end of R_4 measured from inside discal cell

III — width of discal cell from base of M_3 to base of R_3

IV — end of 2nd-A to end of R_4 (indication of the width of the wing)

Measurements were made under a 10 X dissecting microscope with a scale accurate to 0.05 mm. This scale was made by photographing a 30 cm. ruler accurate to 0.5. and photographically reducing the image 10 times on printing paper.

RESULTS

Results of the frequency of spotting analysis show a number of interesting trends. First, the observed frequencies of the occurrence of a spot in all cases were higher in female samples

Table 1

Values of "t scores" of comparisons of frequencies of spotting between populations of Oeneis melissa from the Presidential Range, N. H.

males

	Monticello Lawn	Gulf Tanks	Cowpasture	Bigelow Lawn
Monticello Lawn	_____	0.058	0.474	0.760
Gulf Tanks		_____	0.904	1.37
Cowpasture			_____	2.25*
Bigelow Lawn				_____

*

females

Monticello Lawn	_____	0.585	0.042	0.024
Gulf Tanks		_____	0.610	0.671
Cowpasture			_____	0.187
Bigelow Lawn				_____

* Significant

than in male samples from a given area. In only one case, that of the Cowpasture samples, was the difference between male and female frequencies significant ($P < 0.1$). It is entirely possible that, had sample sizes been larger, a significant degree of difference would have been found between male and female spotting frequencies from the remaining three areas. This is especially true for the Monticello Lawn and the Gulf Tanks areas. Comparisons of male samples showed a significant difference between Bigelow Lawn and Cowpasture ($P < 0.025$), and a difference approaching significance between Bigelow Lawn and Gulf Tanks ($P < 0.2$). All other comparisons of spotting frequency, including those between female samples, showed no significant differences (table 1; figure 2).

Results of the forewing measurement analyses show that females are larger than males on the average, a result which is almost invariable with most butterfly species (table 2; figure 3). All but the Monticello Lawn samples show that this difference is highly significant for measurements I and II (table 3). Again, small sample sizes from Monticello Lawn may account for this discrepancy. Between samples of a given sex from the four areas very few differences even approaching significance were found (tables 4 and 5). Males, however, tended to show greater differences than did females. Once again, little reliance can be placed on values obtained from the male Monticello Lawn sample because of its extremely small size.

DISCUSSION

The results of this study have been inconclusive. However, the data from the five character analyses combined with field observations can be used to draw at least tentative conclusions until further field work can be undertaken.

From the observations of the butterfly, the hypothesis that the population is divided into discrete local breeding populations is likely, especially between the northern and southern portions of the Presidential Range. Between Mt. Jefferson and Mt. Clay, for example, the ridge drops to below 5000 ft. and enters typical scrub vegetation. It is unlikely that *semidea* would fly this low unless it were blown from higher ground. The butterfly rarely flies more than a foot or two above the surface of the ground, so an individual which might accidentally wander downslope would eventually enter completely foreign vegetation and would probably seek higher ground again. This tendency to seek higher ground, more commonly termed hilltopping, has been recorded

Table 2

Mean values and 95% confidence limits of wing measurements made on samples of Oeneis melissa semidea from the Presidential Range, New Hampshire.

Monticello Lawn	I	II	III	IV
male (n=5)	23.9 \pm 0.99	10.4 \pm 0.37	3.0 \pm 0.18	14.6 \pm 0.28
female (n=9)	24.4 \pm 0.82	10.9 \pm 1.5	3.0 \pm 1.34	14.5 \pm 0.34
Gulf Tanks				
male (n=30)	23.0 \pm 0.39	10.1 \pm 0.02	2.9 \pm 0.09	14.1 \pm 0.29
female (n=7)	24.3 \pm 0.83	11.1 \pm 0.73	3.0 \pm 0.25	14.6 \pm 0.50
Cowpasture				
male (n=34)	23.2 \pm 1.04	9.8 \pm 0.59	2.9 \pm 0.19	13.9 \pm 0.95
female (n=12)	24.4 \pm 0.57	10.9 \pm 0.31	3.0 \pm 0.09	14.4 \pm 0.31
Bigelow Lawn				
male (n=20)	23.4 \pm 0.42	10.4 \pm 0.38	3.0 \pm 0.09	14.2 \pm 0.34
female (n=9)	24.9 \pm 0.97	11.3 \pm 0.46	3.1 \pm 0.19	14.8 \pm 0.59

Table 3

Exact percentages (divided by 100) of "t-scores" of comparisons between male and female samples of Oeneis melissa semidea from designated areas of the Presidential Range, New Hampshire.

	ML	GT	C	BL
I	0.608	0.00505**	0.00069**	0.0015**
II	0.120	0.0006**	0.000**	0.0062**
III	1.000	0.326	0.080	0.243
IV	0.684	0.096	0.062	0.055

* significant ($P < 0.05$)

** highly significant ($P < 0.01$)

for many species of butterflies (for review see Shields, 1967) including *Oeneis melissa* (Munroe, 1948 (1951); Anthony, 1969). In the far north and the Rocky Mountains, *Oeneis melissa* flies only above or north of the scrub line. On Mt. Washington and the surrounding peaks of the Presidential Range the only individuals which actively fly appreciable distances are males in search of females. Since the females almost invariably remain in areas where grasses and sedges are the dominant form of vegetation, males tend to congregate in these areas also. Thus, between Mt. Jefferson and Mt. Clay a partial barrier to movement of individuals and genetic exchange exists.

On Mt. Washington itself one interesting relationship seems evident between the three sampled areas. Looking at the t scores for spotting frequency computed between the samples from each of the three areas, the significance of the differences between the samples appears to be almost directly related to their directions from each other relative to the direction of the prevailing wind from the west. Between the Gulf Tanks and the Cowpasture there is more than a 25% chance that the populations have the same frequency of spotting. This is reasonable since the Cowpasture is in the direct path of the prevailing wind from the Gulf Tanks. An individual could be and frequently probably is blown from the Gulf Tanks area into the Cowpasture in a matter of minutes. On the other hand, between the Gulf Tanks area and Bigelow Lawn there is only about a 15% chance that the populations have the same frequency of spotting. Again the directions of Bigelow Lawn from the Gulf Tanks relative to the direction of the prevailing wind would account for the reduced chances that the populations have the same frequency. Finally, between the Cowpasture and Bigelow Lawn there is almost no chance, less than 2%, that the populations have the same frequency of spotting. This is because there is almost no chance that an individual could be blown from one to the other, since a line between them is practically perpendicular to the direction of the prevailing winds. Individuals which are blown anywhere are probably blown directly east or southeast, in the case of the Cowpasture into the Great Gulf or Huntington Ravine, and in the case of Bigelow Lawn into Tuckerman's Ravine or the Gulf of Slides. In addition, the Alpine Garden, which lies directly between the Cowpasture and Bigelow Lawn, is surprisingly devoid of the butterfly, even though in the past it has been regarded as a prime collecting area for *Oeneis melissa*.

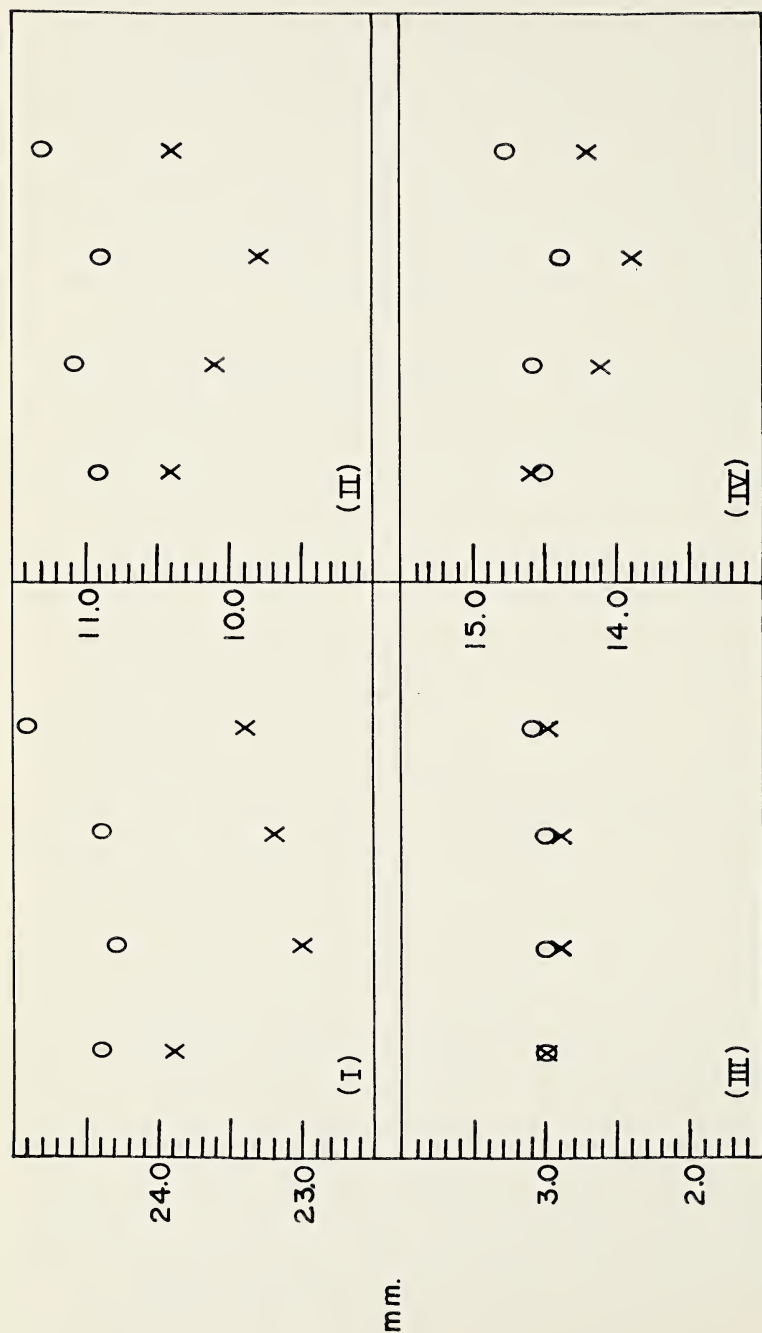


Fig. 3: Diagram of values of measurements made on the forewings of *Oenets melissa semidea* from the Presidential Range, N. H. Roman numerals correspond to those of fig. 1. ML = Monticello Lawn, GT = Gulf Tanks, C = Cowpasture, BL = Bigelow Lawn.

Table 4

Exact percentages (divided by 100) of "t-scores" of comparisons of wing measurements made on samples of Oeneis melissa semidea from the Presidential Range, New Hampshire.

Males

	ML	GT	C	BL	Measurement
ML	*---	0.078	0.199	0.283	(1)
	---	0.249	0.038*	1.000	(11)
	---	0.062	0.301	1.000	(111)
	---	0.159	0.126	0.251	(1v)
GT		---	0.567	0.126	
		---	0.030*	0.122	
		---	1.000	0.115	
		---	0.323	0.652	
C			---	0.543	
			---	0.002**	
			---	0.050*	
			---	0.164	
BL				---	

* significant

** highly significant

Table 5

Exact percentages (divided by 100) of "t-scores" of comparisons of wing measurements made on samples of Oeneis melissa semidea from the Presidential Range, New Hampshire.

c

Females

	ML	GT	C	BL	Measurement
ML	---	0.840	1.000	0.622	(I)
	---	0.586	1.000	0.175	(II)
	---	1.000	1.000	0.657	(III)
	---	0.709	0.748	0.639	(IV)
GT		---	0.814	0.308	(V)
		---	0.506	0.577	(VI)
		---	1.000	0.537	(VII)
		---	0.575	0.589	(VIII)
C			---	0.298	(IX)
			---	0.100	(X)
			---	0.268	(XI)
			---	0.172	(XII)
BL				---	(XIII)
				---	(XIV)
				---	(XV)
				---	(XVI)

Two points must be emphasized in defense of this attractive relationship. First, the period of time during which this butterfly flies during the summer is short, beginning slightly before the first of July with very small numbers of individuals, reaching a peak in numbers by the end of the second week of July, and ending by the last week in July or the first of August, depending on the weather conditions for a given season. This year (1969), the flight period was probably effectively ended by the 22nd of July because of extremely bad weather which began on that date. By the 2nd of August, when the harsh weather had ended, no butterflies were seen anywhere. Since the flight period of the butterfly is therefore so limited, the period during which genetic exchange between local populations is possible is limited as well. Secondly, during this short flight period the number of days during which adults fly is limited by the weather. The butterfly tends to fly in appreciable numbers only on relatively warm, sunny days, which are few and far between in this above tree-line area of the White Mountains. The butterfly generally will not fly in winds above 40 mph., in temperatures below 45 degrees F., or in fog or rain, unless it is disturbed. Since the butterfly then only flies during relatively "good" weather, and since the wind rarely blows from directions other than the west or northwest during such "good" weather, the chance of movement of individuals by wind action alone in any direction other than from west to east is slight.

A number of inconsistencies exist in the data and field observations of *Oeneis melissa semidea*. First of all, comparisons of frequency of spotting made between areas are not paralleled by the comparisons of wing measurements. In fact, the lack of a definite pattern to the comparisons of the wing measurements casts doubt on the validity of these measurements as genetically controlled characters. The fact that many species of *Oeneis* possess a spot in exactly the same area of the wing that certain individuals of *semidea* do would seem to indicate that spotting is indeed genetically controlled and not subject to differences in time of eclosure, nutritional factors, or other environmental conditions. However, overall size of the butterfly, reflected in the measurements, may indeed be influenced by the above factors. Breeding experiments should resolve this question if a successful technique for raising the butterfly can be developed.

Another inconsistency is found in comparing male and female spotting frequencies from a given area and between areas, and at the same time recalling that the females of this species are more

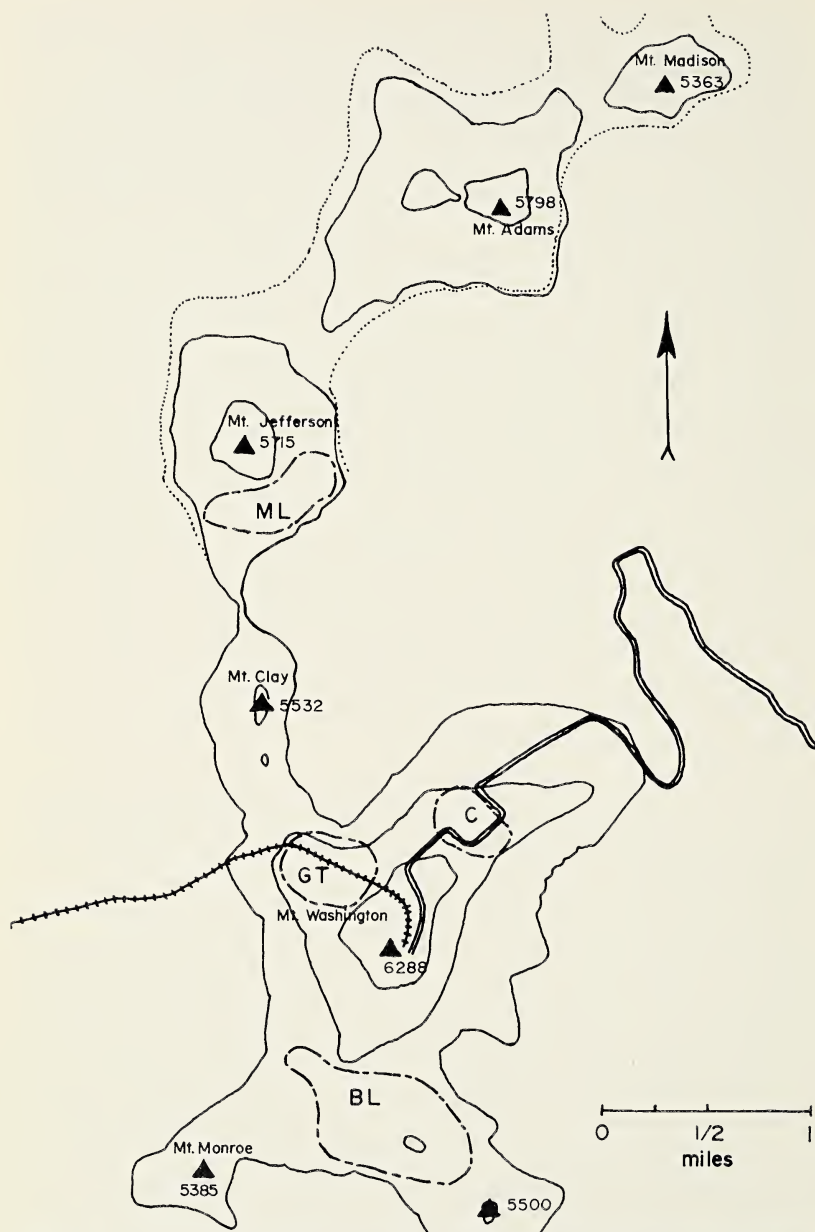


Fig. 4. Map showing above tree line areas of the Presidential Range, New Hampshire.

Areas sampled for *Oeneis melissa semidea* indicated by large capital letters, inclosed by dashed line. ML = Monticello Lawn, GT = Gulf Tanks, C = Cowpasture, BL = Bigelow Lawn.

or less sedentary, whereas the males tend to wander. In this case the question arises as to why the female spotting frequencies are statistically constant and do not at least parallel the males. The only explanation for this that so far appears to be tenable is that the males, because they fly more often and for greater distances are therefore more exposed than the females and are consequently subject to some unknown selective pressure more than are the females. This selection pressure may be resulting in more variation in the male populations than in the female. An interesting point to mention is that there seems to be a slight correlation between the presence of a spot on a given individual and the distinctness of the dark median band on the ventral surface of the hindwing. If indeed there is a correlation between these two characters, then a basis can be laid for suspicion of predatory pressure favoring spotted individuals through selection for a distinct band. It has been proposed that the white band which crosses the wings of certain species of *Limenitis* butterflies produces a form of disruptive coloration, breaking up the outline of the wing and rendering it less easily seen by a potential predator (Platt and Brower, 1968). It seems possible that adult *semidea* are under selective pressure from predators such as certain species of birds which frequent the alpine areas of the Presidentials, and that the distinctness of the median band of the hindwing (which is exposed when males sun themselves on rocks) and likewise the presence of a spot on the forewing is being influenced by this pressure. It is also interesting to note that another species of *Oeneis*, namely *polyxenes*, is found in a very similar arctic relict environment on Mt. Katahdin in Maine. All individuals of this population possess a spot in exactly the same area of the forewing and all are rather invariably distinctly banded. *Oeneis melissa* from the Presidentials, on the other hand, vary considerably in not only the presence but the overall development of a spot as well as in the distinctness of the median band. Unfortunately, no objective means could be devised for determining whether or not a band is distinct, and hence the correlation between band and spot has yet to be statistically shown.

SUMMARY AND CONCLUSIONS

Oeneis melissa semidea from the Presidential Range of New Hampshire was studied in the field, and samples from four areas of the range were taken in an effort to determine the popula-

tion structure of the butterfly. Statistical treatment of five characters yielded no conclusive evidence for either total isolation or lack of isolation between the populations inhabiting the four areas, but field observation combined with the statistics derived from the frequency of the occurrence of a spot on the forewing of the butterfly indicate that at least partial barriers probably exist between the sampling areas. Movement of individuals between any of the areas was not seen while in the field. Movement by action of the prevailing wind from the west is discussed and cited as probably the major contributor to the breakdown of any spatial or environmental barriers which do exist.

ACKNOWLEDGMENTS

I wish to thank Dr. Andrew Nelson and Dr. John Gilbert for their guidance and assistance in planning and carrying out this undertaking, the crew of the Mount Washington Observatory, especially Guy Gosselin, the Chief Observer, for their hospitality and company, and the Undergraduate Summer Research Fellowship Committee of Dartmouth College for making this summer's work possible. This work was supported by a fellowship derived from PHS grant number 5 TO1 HE 5303-11.

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A HYBRID *LIMENITIS* FROM NEW YORK

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AN APPARENT HYBRID between *Limenitis arthemis* Drury and *L. archippus* Cramer (Nymphalidae) was taken by one of us (AMS) on 6 August 1967 in Dryden Township, near Ithaca, Tompkins County, New York. The specimen (figs. 1, 2) is a male in fresh condition. It agrees in most respects with the published description of *L. X arthechippus* Scudder (1889), and the upper surface is nearly identical to one of the bred examples figured by Field (1914).

There are at least four prior records of this hybrid from the Northeast, plus one involving the northwestern subspecies of *L. arthemis*, *rubrofasciata* B. & McD. The type specimen was first described by Edwards (1882) as *L. arthemis*, ab.C. The same specimen later served as the type of Scudder's *arthechippus*. It was collected at Chateauguay, Que. (vic. Montreal) by J. G. Jack in 1879. The other Eastern records are all from Field, who collected somewhat darker specimens at Alstead, N. H. in 1895 and 1896, and saw another in 1902 (Field, 1904). The Western specimen was collected at Beulah, Manitoba, and described as *L. X rubrofasechippus* by Gunder (1934). There seem to be no recent records from the East.

The somewhat similar *L. X rubidus* Strecker, a putative hybrid of *L. archippus* and *L. astyanax* Fabr., is known from Berks Co., Pa.; Jeannette, Westmoreland Co., Pa.; Wellesley, Mass.; "Sharpborn" (Mass.?), Brooklyn, N.Y.; and "eastern N. Y." (probably Catskills). A recent example collected at Louisville, Ky. was described by Monroe (1953).



Fig. 1. *Limenitis* from Tompkins Co., N. Y. Upper surfaces. Top Left: *L. arthemis* ♂, Cayuga Inlet Valley, 3.viii.67 (AMS). Top right: *L. archippus* ♂, Monkey Run, Dryden, 6.viii.67 (AMS). Bottom: *L. X arthechippus* ♂, Monkey Run, Dryden, 6.viii.67 (AMS).



Fig. 2. Lower surfaces of the specimens shown in Fig. 1.

The sexes of the *rubidus* are not known, but all of the *archippus* recorded are males. Field (1914) reported an experimental cross of reared female *archippus* X wild male *arthemis*. He obtained poor egg hatchability (19/62) and an abnormal sex ratio (8♂:0♀ plus a dead pupa probably male; for 9:0 with expected 1:1 $\chi^2=9.0$, $P<.005$). The preponderance of males is in accord with Haldane's Rule. Other broods of hybrid *Limenitis*, reared by Remington, also show this phenomenon (Remington, 1958).

The very different coloration of *L. arthemis* and *L. archippus* would suggest the existence of strong behavioral barriers to hybridization. Through most of their range the two species are strongly, but not totally, isolated on an ecological basis, *arthemis* being essentially a woodland insect while *archippus* occurs principally in open country. In this connection it is of interest that the Ithaca hybrid was taken in a disturbed, ecotonal area in close proximity to typical habitats frequented by the parent species. On the same stand of Teasel (*Dipsacus sylvestris* Huds.) with the hybrid were several normal *archippus*, one of which is figured, while in the woods several hundred feet away, fresh *arthemis* of the second brood were flying. The known food plants of *L. arthemis* near Ithaca are *Populus tremuloides* Michx. and *P. deltoides* Marsh. *L. archippus* has been reared locally on *P. deltoides* and observed ovipositing on willows (*Salix*). Of these, *Salix* spp. & *P. tremuloides* were present in the vicinity of the collection site.

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THE POPULATION BIOLOGY OF THE NEOTROPICAL SATYRID BUTTERFLY, *EUPTYCHIA HERMES*.

I. INTERPOPULATION MOVEMENT, GENERAL ECOLOGY, AND POPULATION SIZES IN LOWLAND COSTA RICA (DRY SEASON, 1966).

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NO THOROUGH STUDY OF LEPIDOPTERAN POPULATION STRUCTURE in the Neotropics has been done, yet the butterflies reach their greatest diversity in this biogeographic realm. The present investigation of *Euptychia hermes* Fabricius (Satyridae) is the first to involve a neotropical satyrid butterfly, and because the species ranges north to the Atlantic coast of the United States the choice of this *Euptychia* will allow future comparisons of the structure of both temperate and tropical populations of the same species. Reported here are data obtained on population size and intrapopulation and interpopulation movement in populations of *E. hermes* located in western and eastern Costa Rica, in Central America.

MATERIAL AND METHODS

Euptychia hermes is a small satyrid, dull brown in ground color, and with a wingspread of about 25 mm. The sexes are similar in coloration and pattern. On the undersides of the wings are several reddish-brown lines (submarginal and limbal positions) and a number of marginal ocelli. The ocelli are rather indistinct on the forewings, but on the hindwings, six well-marked ocelli are present (Figure 1). The degree of development of these hindwing ocelli was used as an index to phenetic variation (data to be reported later).

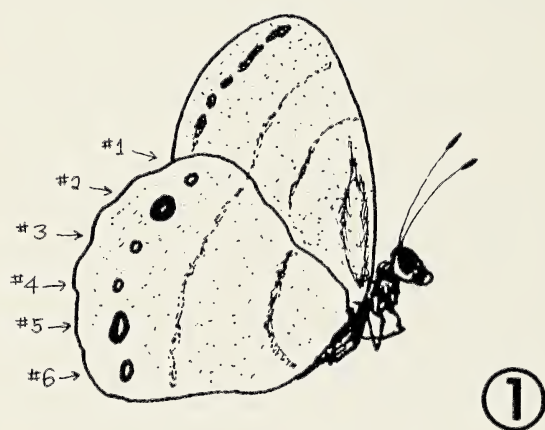


Fig. 1. *Euptychia hermes*: ventral surface, showing ocellation pattern.

A capture-mark-release-recapture program to determine population size and extent of individual movement was carried out in a series of populations in Guanacaste Province (four successive days) and in one population in Limón Province (six successive days). Magic-Marker ink pens were used to mark the individual butterflies on the wings by a code system (Ehrlich and Davidson, 1961). As this butterfly was found to be most active in the early morning, all marking studies were done between 7:00 and 9:30 a.m. and repeated daily. Each area was sampled once a day to avoid the complication of same-day recaptures. All butterflies flying in a population could be captured in 30 to 40 minutes at most, and the earlier captures were retained in extra nets until that time when all specimens were marked (or recorded if a recapture) and then released again.

DESCRIPTION OF STUDY AREAS

I. Guanacaste Populations (Western Costa Rica):

A series of five populations were located along a thousand-foot (300+ meters) section of the river road east of the experimental station of the Costa Rica Ministry of Agriculture and Livestock, adjacent to the Finca Taboga, located 13.5 km. southeast of Cañas, Guanacaste Province, at an elevation of 11.5 meters (38 feet) above sea level. The study was carried out February 13-16, 1966.

The general vegetational formation was dry tropical deciduous forest, in a late stage of second-growth recovery along the road where a series of grassy "islands" were surrounded by vine-covered shrubs and dense undergrowth except on the road side, and were isolated from each other by differing expanses of dry habitat. The small meadows were bordered on the east by a swamp, the source of moisture for the green grasses. *Euptychia hermes* at this location was abundant in these grassy areas; individuals were occasionally encountered elsewhere in the dry forest. The entire group of colonies in the study area was isolated from other grassy regions along the road by at least 250 feet (70 meters). Figure 2 shows the spatial orientation of the population sites.

The grasses were one-third to one-half meter in height; the surrounding vines and shrubbery were 1.5 to 2 meters and more in height. The butterflies flew over these latter "barriers" on occasion, but usually flew *into* them through slight "holes" in the leafy wall, when pursued or when the sun rose higher in the late morning. Second-growth plants found in the study area

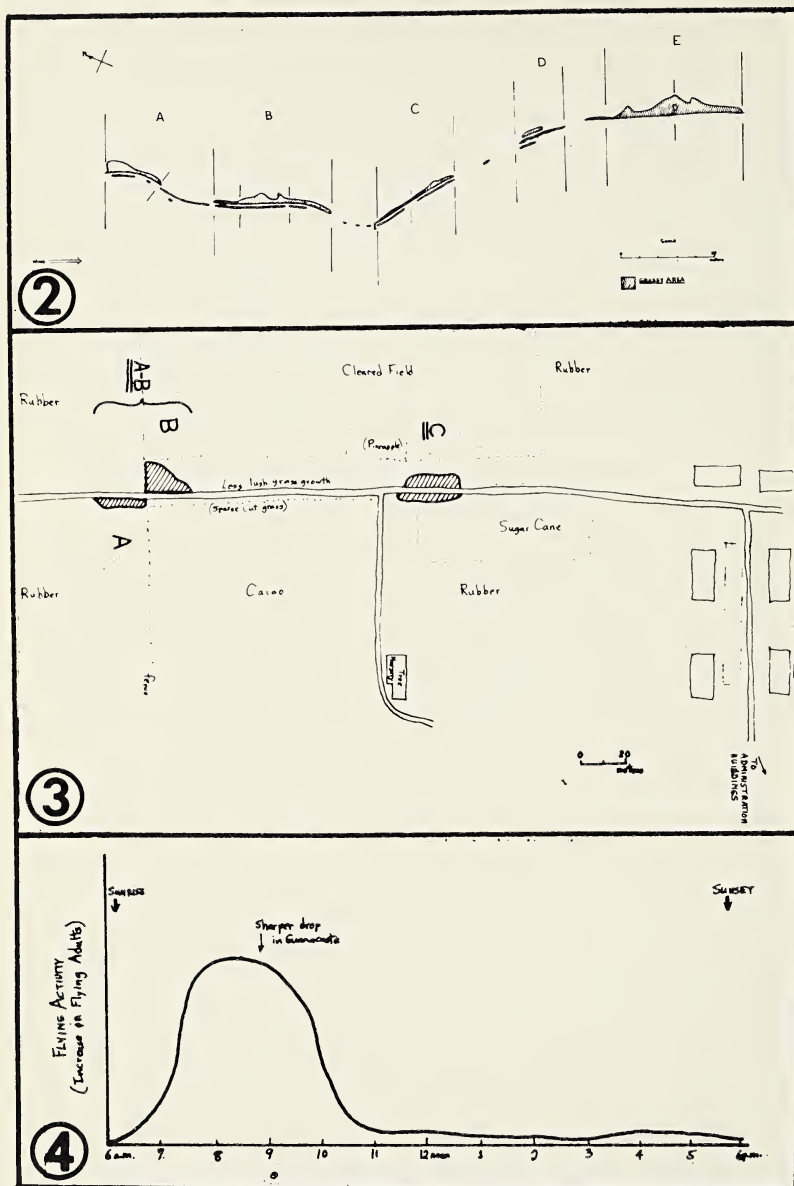


Fig. 2. The spatial orientation of the population sites studied along the river road on the Finca Taboga, southeast of Cañas, Guanacaste Province, Costa Rica.

Fig. 3. Map of the population areas studied on the Los Diamantes experimental station grounds, east of Guápiles, Limón Province, Costa Rica.

Fig. 4. Daily fluctuation in flight activity of *Euptychia hermes* at the low-land Costa Rican study sites: open meadow populations.

were: *Solanum* (3-4 meters high, a border tree), two species of *Salvia* (Labiatace), *Oenothera*, *Cassia* (a border tree), several species of vines (Convolvulaceae and Vitaceae), *Philanthus* (Euphorbiaceae, a border plant), *Triplaris* (a border tree), *Panicum* grass) and two unidentified grasses (one of which the butterfly flew around and frequently landed on).

The daily weather here was sunny and hot with intermittent clouds. During the hours of the capture-recapture studies, the temperature ranged from about 75 to 86°F., a daily maximum of 96 to 98°F. was usual. The relative humidity was around 50%. A strong gusty wind developed by 9:15 a.m. every day.

II. *Los Diamantes Populations (Eastern Costa Rica):*

The capture-recapture study was done March 4-9, 1966, on a population inhabiting a lush grassy area surrounded by cleared fields and cacao and rubber plantations (these areas with grasses also), located about a half kilometer northeast of the buildings at the Los Diamantes experimental station of the Costa Rican Ministry of Agriculture and Live-stock, 1 km. east of Guápiles, Limón Province, at an elevation of 300 meters (984 feet). An adjacent population was sampled to study local variation patterns (see Figure 3 for map).

The grasses were lush on the east side of the road and up to 35 cm. in height; many *Euptychia* were flying here. On the west side of the road, the grass had been cut short and few butterflies occurred there. In Area C, many *Euptychia* were landing on crushed sugar cane stalks in the road and sipping the sap. The peak of butterfly activity, as at Guanacaste, was between 7:00 and 9:30 a.m. The daily weather was warm, from about 72 to 80° during the capture-recapture periods, and up to 86° or so as a daily maximum. Partly to completely cloudy skies, with occasional showers, were the rule. Relative humidity ranged from 85 to 100%.

A small sample of adults from the nearby and largely uncut rain forest, 8 km. west of Guápiles (by the Río Toro Amarillo), was taken; the butterflies were very scarce and scattered there, despite apparently satisfactory grassy areas along the roads.

GENERAL BIOLOGY & ACTIVITY OF *EUPTYCHIA HERMES*

When the first morning sun hits the grassy site of a population around 7 a.m., the *Euptychia* begin flying. During the following two hours, they are quite active and drink sap from crushed

sugar cane and suck water from mud in the road bed. By 9:30 a.m., when the full sun is quite intense, there is hardly a butterfly to be seen in the open. This lack of activity in open areas continues through the rest of the day. In Guanacaste, it was noted that a few were flying in the shade or in the undergrowth, wherever they were protected from the sun and partly protected from the strong winds. The daily activity cycle is roughly graphed in Figure 4.

This *Euptychia* is a low-flying butterfly, clearing the ground or tops of grass blades by only a few inches. It frequently rests on the broad-bladed grasses. No oviposition was observed. No evidence of larvae could be found, but this is usual for satyrid populations because of the nocturnal larval feeding habits and the known behavior in several nearctic satyrids of eating the entire grass blade, leaving little or no evidence of activity.

One mating attempt was observed at 8:45 a.m. February 14 at Guanacaste. A female landed on a partially-sunlit horizontal grass blade and a male, which had been following her closely in flight, landed behind her. He walked rapidly up on her left side and curved his abdomen around in a U-shape into a copulating position, but the female was skittish and moved away slightly. At this point, a second male landed ahead of the female and rushed towards the pair; all three butterflies immediately flew away in separate directions.

Euptychia hermes was sympatric with three other *Euptychia* species at Guanacaste, and with one of the same species at Los Diamantes in Limón Province.

Analysis of the age composition (as determined by fresh, intermediate or worn conditions of wings, and the daily addition of fresh adults) of the male and female samples of all populations indicated a continuous emergence well before and during the study period in both the western and eastern populations. There is no reason to doubt the belief that this *Euptychia* breeds continuously throughout the year in these lowland forests (surprisingly even during the dry season in the deciduous forest, wherever moisture for green grass is available), as larval food is apparently available at all seasons and the species is known to occur at all seasons in tropical parts of eastern Mexico (Emmel, unpublished data). Therefore the species probably does not have a diapause stage in these tropical populations. It would be of interest to carry out comparative physiological and genetic studies with *E. hermes* since the extra-tropical populations in the north, which face severe conditions with a cold winter instead

of a dry season, apparently have a genetically controlled, obligatory diapause in the larval stage.

A red Orbatid mite was found on the dorsal surface of the abdomen on each of two females in the Los Diamantes area; these mites were firmly attached and feeding. No bird attacks or other predation were observed. No flower-feeding by the adults was ever noted, so it is unlikely that reduviid bugs, mantids or crab spiders are significant predators.

POPULATION SIZE ESTIMATES

I. Guanacaste Results:

During the first three days, 59 adults were marked and released, with 32 new adults added in sampling on the fourth and final day of study. Of the 59 releases, 7 (3 males, 4 females) were recaptured at least once, 1 female was recaptured twice, and 1 female was recaptured on all three days following the day it was marked. No marked butterfly changed from one population area to another. Only one individual was recaptured in a marked population other than E, so estimates of population size (total number of individuals flying daily) were restricted to population E, using a simple Lincoln-Index proportion calculation.

<i>Est. Population Size</i>	<i>Date</i>
110 adults	February 14
75 adults	February 15
234 adults	February 16

Allowing for vagaries of individuals and varying weather conditions, these figures give an approximate population size of between 75 and 250 adults for a grassy area of only about 30 square meters. It is likely that individuals move back into the undergrowth in daily wanderings and may be absent from the grassy stand for a day or two. Variations in apparent flying-adult population size are known to be due to these environmental and "wandering" factors, among others (Emmel and Emmel, 1963).

II. Los Diamantes (Limón Province) Results:

A total of 57 adults were marked and released in population A-B during the first days of the study; three more were sampled on the sixth day. Of the 57 releases, 8 were recaptured once; none was recaptured twice. The marked irregularity of recapture of marked adults (none on three days) permits estimates for only the following three dates:

TABLE 1
Sex Ratios in the Guanacaste Populations:
Daily New Captures (1966)

Population	Feb. 13		Feb. 14		Feb. 15		Feb. 16		Population totals	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
A	-	-	2	0	-	-	-	-	2	0
B	3	0	2	0	1	0	1	0	7	0
C	-	-	4	2	6	3	6	1	16	6
D	-	-	-	-	-	-	2	1	2	1
E	4	6	10	10	3	3	16	6	33	25
Daily Totals:	7	6	18	12	10	6	25	8	60	32
									(92 adults) Ratio=1.88:1.00, ♂: ♀	

<i>Est. Population Size</i>	<i>Date</i>
109	March 6
299	March 8
143	March 9

Since individuals were frequently seen entering and leaving Area A-B, and since all but one recaptures were females (and females are notably more sedentary than males in this and all other butterfly species studied to date) and none was recaptured more than once, it seems probable that this supposed "population" is merely a concentration of individuals in a section of a much larger population, whose individuals range into the rubber groves and adjacent fields for at least 30 meters or more (observed distance of flight of several males). This lush grass area is also likely a favored oviposition site for the females (note the preponderance of females here, in Table 2, as compared to the "normal" preponderance of males in Population C and in Guanacaste populations).

SEX RATIO IN POPULATIONS

The overall sex ratio in the Guanacaste populations was 1.88 males: 1.00 female (Table 1). Most females occurred in population E here, which apparently was the only stable resident population in view of the capture-recapture results.

In the Los Diamantes populations, the overall sex ratio was 0.95 males : 1.00 female (Table 2). When the transient "population" A-B (sex ratio of 0.58 : 1.00) is considered separately from the apparently "resident" population C, though, the latter (sex ratio of 1.41 males to 1.00 females) is seen to be similar in its male-dominated sex ratio to the Guanacaste populations.

EXTENT OF INTRA- AND INTER-POPULATION MOVEMENT

There was no observed interchange of individuals between any of the Guanacaste populations (delineated by shaded areas on the map in Figure 2); thus these appear to be reproductively isolated breeding units. The same conclusion is reached for the Limón populations from the lack of interchange of marked individuals between Area A-B and Area C at Los Diamantes. From the available evidence, then, a distance of several score meters or less (only 20 meters between areas A and B in Guanacaste) of unsuitable habitat appears to effectively separate populations of this *Euptychia* species. Further study is needed here to de-

TABLE 2

Sex Ratios in the Los Diamantes Populations:

Daily New Captures (1966)

Population	Mar. 4		Mar. 5		Mar. 6		Mar. 7		Mar. 8		Mar. 9		Population Totals	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀ Ratio
A-B	10	13	1	5	3	8	3	3	3	8	2	1	22	38 0.58:1.00 ♂ ♀
C	-	-	-	-	6	3	7	6	15	12	17	11	45	32 1.41:1.00 ♂ ♀
Daily Totals:	10	13	1	5	9	11	10	9	18	20	19	12	67	70 0.96:1.00 ♂ ♀ 137 adults total

termine the precise amount and type of barrier required for isolation; quite likely, the barriers to dispersal are intrinsic (genetically-controlled) as well as environmental, since this butterfly is capable of flying over thirty meters when pursued and can fly through tangled undergrowth without much hesitation.

The marked butterflies in subareas E_1 and E_2 of the Guanacaste Population E, and in subareas A and B of the Los Diamantes Population A-B, exchanged daily positions back and forth within the total population area with equal frequencies. From observation of flight behavior, also, there was no evidence of territorial or homing behavior in either males or females. This is in contrast to data obtained on the nearctic lycaenid butterfly, *Plebejus icarioides*, where both sexes usually stay in their "home" part of the population area and will return to it if displaced (Emmel, ms, in prep.).

DISCUSSION AND CONCLUSIONS

The general findings of the present study concur with many population parameters characteristic of the majority of investigated temperate-zone butterflies. This *Euptychia* exhibits about the same degree of sedentary behavior as the satyrid *Cercyonis oetus* (Emmel, 1964, unpublished); the lycaenids *Plebejus icarioides* (Emmel, ms. in prep.), *Philotes sonorensis* (Mattoni and Ralston, ms. in prep.), and *Polyommatus icarus* (Dowdeswell et al., 1940); the nymphalid *Euphydryas editha* (Ehrlich, 1961, 1965); and the pierid *Anthocaris sara* (Evans, 1955). In other words, the species fails to exercise its apparently high degree of vagility, the ability to cross barriers. Capture-mark-recapture studies confirmed that while intrapopulation movement occurs regularly, interpopulation movement is of such insignificance that these populations are effectively genetic isolates, despite being separated, in some cases, by only about twenty or thirty meters of unsuitable habitat.

The species is most active in the early-morning hours and the later decrease in flight activity may be due to wind (at Guanacaste) and solar radiation reaching relatively intolerable levels as the day progresses. *Euptychia hermes* most likely breeds continuously throughout the year in these tropical populations, even in areas having a pronounced dry season. One might suppose that populations increase and disperse to make essentially continuous huge populations in many areas during the wet season, when more green grasses would be available. However,

the fact that such large continuous populations were not found in the eastern wet rain forest areas mitigates against this hypothesis. Since the distribution of the species in lowland Costa Rica seemed closely tied to that of a certain broad-leafed grass (still to be identified), foodplant specificity may control the butterfly's distribution more than any particular environmental factor. Such a situation is suspected for the satyrid *Cercyonis meadi* in the western U.S., which occurs in widely-scattered, small populations from 5000-foot-elevation juniper woodlands to 10,000-foot-elevation mountain pine forests, always in association with particular grass species (Emmel, unpublished).

SUMMARY

Population sizes, intrapopulation and interpopulation movement, and local and geographic phenetic variation were analyzed in grassy meadow populations of the satyrid butterfly, *Euptychia hermes* Fabricius, located in western and eastern Costa Rica (Finca Taboga, Guanacaste Province; and Los Diamantes, Limón Province). Population size was determined by mark-recapture experiments; a typical population site of 30 square meters in area had between 75 and 250 flying adults in it during the dry-season study period.

No movement of marked individuals occurred between populations separated by as little as 20 meters of dry or non-grassy areas, yet the butterflies moved freely around within a population area and when deliberately forced to, could fly more than 30 meters linear distance. Thus, intrinsic (genetic) factors probably play the major role in limiting flight movement and dispersal.

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A REARING TECHNIQUE FOR SPEEDING UP THE LARVAL STAGES OF SOME ROOT OR STEM-BORING LEPIDOPTERA

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LARVAE THAT BORE IN ROOTS, stems, or tree trunks (cossids, aegeriids, etc.) can sometimes be reared with convenience, and at a great saving of time and trouble, by providing them with raw sweet potatoes, white potatoes, yams, beets, turnips, parsnips, or carrots, etc., into which they can bore.

If they will accept one of these substitutes, growth is often more rapid than under natural conditions. In Kansas I had excellent results with *Prionoxystus robiniae* Peck (Cossidae), by providing the newly-hatched larvae with raw potatoes (both white and sweet), which they readily accepted, even though in nature they bore inside cottonwood (*Populus*), and other tree trunks; growth was completed in less than one year, and healthy adults emerged shortly after pupation. It is necessary to remove the larva from the potato, or whatever vegetable is found suitable, when it has been mostly consumed inside or is beginning to spoil. Time will vary according to the vegetable used. To start the larva into a fresh potato, make a hole in the potato and thrust the larva's head inside; it will usually proceed to bore in without further attention. Boring larvae are sometimes inclined to kill each other when crowded, so they should be permitted to lead solitary lives, particularly as they grow larger.

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HABITAT: *EUPHYDRYAS EDITHA WRIGHTI*

Vernal pools are an interesting feature of the coastal mesas of Southern California. These pools form in shallow depressions which are underlain by an impervious layer, and are surrounded by low mounds of earth. These depressions fill with rainwater in the winter and since there is no drainage, the water remains until it slowly evaporates in the spring. This novel habitat is ancient enough to have developed a unique flora and fauna. Among the plants is *Plantago insularis*, which in pure stands resembles a lawn. This is the foodplant of *Euphydryas editha wrighti*.

This habitat is being rapidly destroyed as people crowd into the coastal areas. As a result this butterfly is becoming difficult to find in areas where it was abundant twenty years ago. Fortunately *P. insularis* is not confined entirely to vernal pools, since slow drainage around the lower edges of slabs of rocks, and perhaps other situations, also provide small areas where this plant can grow in the foothills. Small colonies of *wrighti* exist in some of these spots, hopefully at densities which will permit survival. (Fig. 1).

Fred Thorne



Fig. 1.—Photo taken two miles west of Sweetwater Dam looking north toward Dictionary Hill, San Diego County, by William A. Hedges.

NOTICES

BOOKS:

BUTTERFLIES. A concise guide in colour. Josef Moucha, ill. by Vlastimil Choc. Paul Hamlyn, Hamlyn House, The Centre, Feltham, Middlesex. G.B.

BIOGEOGRAPHY OF THE SOUTHERN END OF THE WORLD. Philip J. Darlington, Jr. McGraw Hill paper back reprint, N.Y.

THEORIES ON THE NATURE OF LIFE. Giovanni Blandino, S.J. Philosophical Library, N.Y.

INTRODUCTION TO ZOOLOGY. Theodore H. Savory. Philosophical Library, N.Y.

WANTED:

Brephidium exilis, *B. fea*, *B. isophthalma*. Life material and specimens for distribution study. Roy Jameson, 2429 Wordsworth, Houston, Texas 77025.

ARGYNNIS. Local and world wide, for world biogeographic study. Also related forms under whatever name. William Hovanitz, 1160 W. Orange Grove Ave., Arcadia, California 91006.

IN PREPARATION:

BUTTERFLIES OF NORTH AMERICA. William Hovanitz. Illustrating in color all the species and races of butterflies of the Nearctic region. Will be the first book on butterflies to use the *New Systematics*, biogeographical and genetic approach to an understanding of this group of insects.

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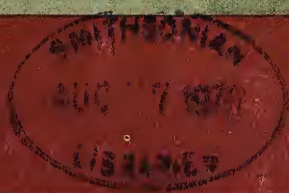
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A STUDY OF
A CONTINUOUSLY BREEDING POPULATION
OF *DANAUS PLEXIPPUS*

IN SOUTHERN CALIFORNIA COMPARED TO A MIGRATORY
POPULATION AND ITS SIGNIFICANCE
IN THE STUDY OF INSECT MOVEMENT.

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² *Dept. of Biology, Whittier College, California*

INTRODUCTION

EARLY IN OUR STUDIES of the movements of the monarch butterfly, it was considered that this species in North America formed a single, gene-flow population the members of which migrated from north to south in the late summer and fall returning the following spring — thus representing a movement similar in many respects to that of a species of migratory bird (Urquhart 1960). However, it was found that in certain parts of North America there were apparently populations that continued to breed throughout the entire year, as in southern California and Florida, or throughout the winter months, as in southwestern Arizona (Funk 1968). Whether the latter population breeds throughout the summer months as well is not indicated. It had also been noted that it is possible to keep breeding populations throughout the year under laboratory conditions (Urquhart & Stegner 1966). It was further observed that females of a migrating population, or those found on over-wintering roosting sites, such as the one located in the Monterey Peninsula of California, failed to oviposit when brought into the laboratory, whereas gravid females collected in the field in the summer and fall laid eggs that gave rise to successive generations (Urquhart & Stegner op. cit.). This has made it possible to have a continuous population for our laboratory experiments on various aspects of insect physiology.

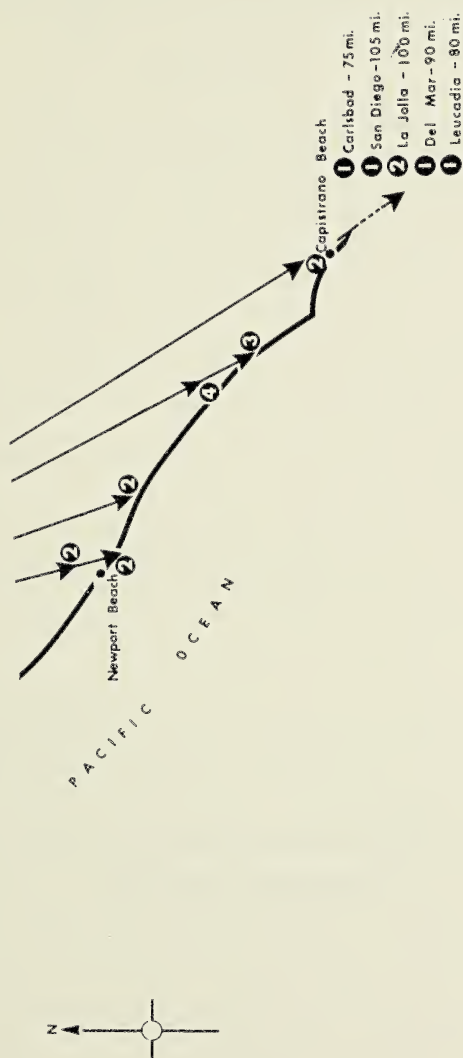


Fig. 1: Flight lines of the movements of monarch butterflies from the release point at Whittier, California. Explanation in text.

As a result of these considerations, and in conjunction with our world-wide studies of the migratory habits of *D. plexippus* and with particular reference to the eastern North American population (Gulf Coast Population, Urquhart 1966) a study of the movements of the population in southern California (release point at Whittier) was commenced in 1964.

METHOD

Of the specimens constituting the population studied, most were reared under natural conditions but some were reared under conditions of artificial light and temperature. A preliminary study of the data for these two populations indicated no significant difference in their flight behaviour and therefore the two populations are considered as a single population reared and released in Whittier and southern California.

On reaching the imago stage, the specimens were tagged, using the marginal alar tag method, and released. The time and place of the release of each specimen were recorded. Data concerning direction and duration of flight were obtained from recaptured specimens that were mailed to our laboratory at the University of Toronto. All data was recorded and all letters of correspondence concerning each recapture were kept on file for future reference. Preliminary maps and flight charts were constructed so as to indicate whether or not movements were taking place and whether or not they were significant.

PRESENTATION OF RESULTS

A total of 8816 imagoes of both sexes were tagged and released and of these 401 representing both sexes were recaptured and sent to us. The present study is based on the data from these recaptured individuals.

Recapture of specimens that had flown more than one mile from the point of release, and hence indicate a significant movement, were plotted on the map of Los Angeles and Vicinity (fig. 1). Each release-recovery line represents the flight of one or more butterflies. The "v" mark indicates the place where the specimen was recaptured and the number beside the mark shows how many specimens were recaptured at that particular point. The flights of specimens which were on the same flight path were joined together in order to show more clearly the movement of the population in a particular direction. Names of places have been included in order to orient the flight patterns and

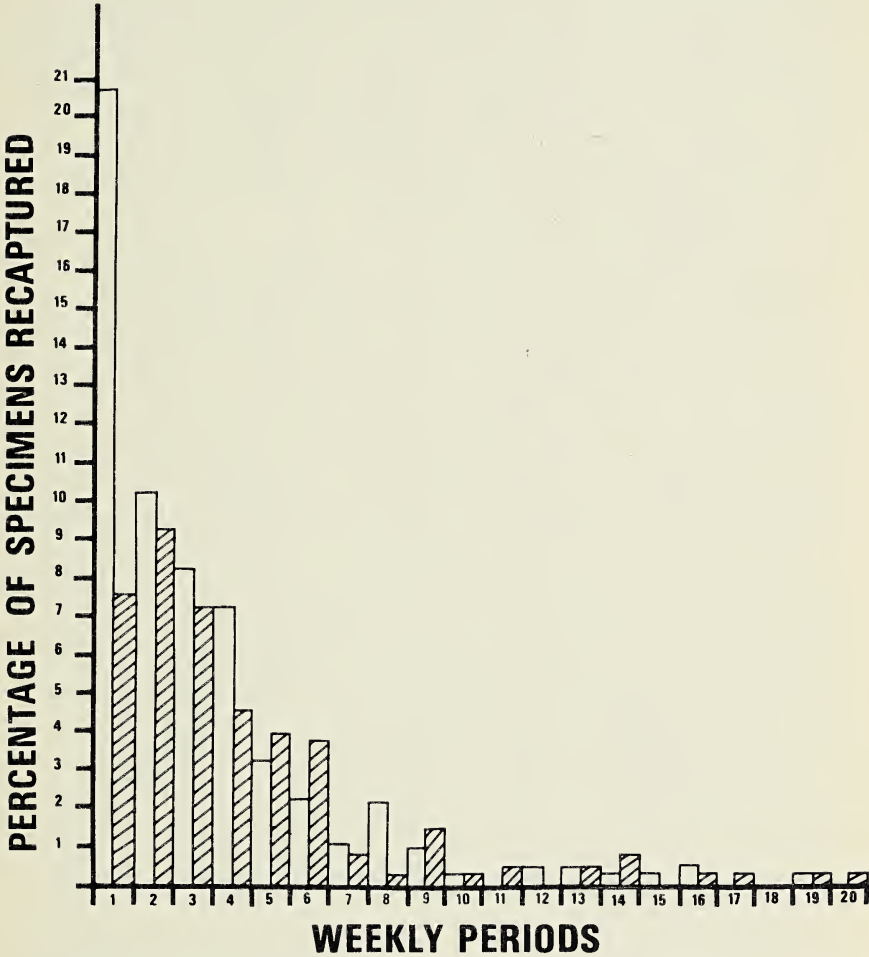


Fig. 2: Histogram indicating percentage of recaptures at weekly intervals.

hence such place names do not necessarily indicate a particular point of recapture. Long flights that extended beyond the area of the map are indicated on the margin with a notation giving the distance from Whittier to the particular place indicated.

The specimens were released in a well-populated area of Metropolitan Los Angeles which made it possible to obtain a high percentage of recaptures — 4.5% as compared to the usual 2% — from all compass points. If releases had been made in a rural district, then areas of no recaptures would have occurred owing to the absence of humans and not necessarily an absence of flights in these particular directions.

An examination of the flight pattern (fig. 1) indicates that there are relatively few flight lines in the sector extending from northeast to west and that the majority of flight lines are to the southwest, south and southeast with the longest flight lines to the south-southeast. There is a conspicuous lack of flight lines in the sector southeast to east, with the exception of a few short flights to the southeast. The absence of long flight lines in this direction might be due to the presence of the Chino Hills and the Santa Ana Mountains deflecting the line of flight, or the sparse human population in this area, or a combination of both factors.

The histogram (fig. 2) shows the time period, in weeks, of recaptures. As one would expect, when a number of specimens are marked and released at a particular geographical locality, there would be more recaptures in the area of release than remote from it. It will be noted that a high proportion (20.8%) of recaptures were made during the first week and had flown less than one mile. A much smaller number (7.6%) traveled more than one mile before being recaptured during the first week.

There is a marked drop in the number of recaptures during the second week, as a result of the thinning out of the population away from the point of release. This is followed by a more gradual decrease in recaptures which finally becomes stabilized after the ninth week.

In the fifth and sixth week more specimens are recaptured after flying more than a mile as compared to those that had flown less than a mile. A similar situation occurs at week nine and week fourteen. This indicates that more individuals of the population had moved away from the point of release than had remained. There is a marked decrease in the number of specimens recaptured after the tenth week reaching a more constant level as the tagged population became more thinly spread out over the countryside and entered those areas of less dense human population.

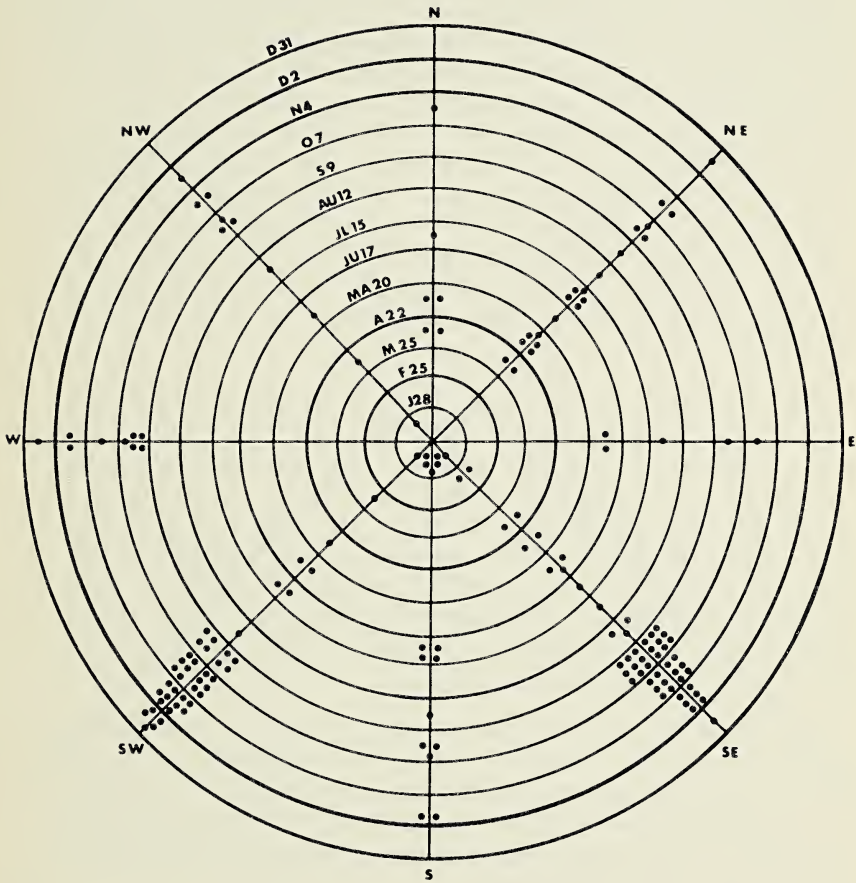


Fig. 3: Movement of Monarch butterflies at various times of the year. Explanation in text.

Thus it would appear from the data here presented that within this population some individuals tend to be resident (58%) while others tend to migrate (42%). The proportion of resident individuals might be considerably less than here indicated, however, because as a result of a dense population of tagged specimens located at the point of release, more of them would be recaptured before being able to move out. If, for example, some method could have been employed so that no specimens were recaptured for an arbitrary period of say two weeks, then there would be a greater chance for tagged specimens to move out of the congested area thus decreasing the percentage of what appears to be resident specimens. Of the total number recaptured, 75.5% were recaptured by the end of four weeks and 89.8% by the end of eight weeks while only 6.8% were recaptured between the end of the eighth week and the end of the 20th week. This can be correlated with the decrease in density as the tagged specimens spread out over the countryside away from the point of release.

Fig. 3 presents a graphic analysis of movements of individuals of the population to compass direction at various times of the year. Each concentric line represents intervals of four weeks, commencing at January 1 at the center point. Thus, the first concentric ring represents January 28; the second ring, February 25; and so on. For ease of reference, the month periods have been indicated. The direction of flight is given to eight points of the compass and each recaptured specimen is represented by a dot. Specimens recaptured at the point of release have not been included in the chart.

It will be noted that there is a strong southerly movement between September 9 and December 2. Although movement tends to be random between January 1 and September 9, there is a marked tendency for a northeast flow between March 25 and July 15. Very little directional movement is indicated between July 15 and September 9.

If we examine the movement for the entire population, with the exception of those recaptured at the point of release, and using the method of Williams (1930), in which each arrow point represents a recaptured specimen it becomes obvious that there is a very definite movement away from the point of release towards the southeast and the southwest (fig. 4). There is also a definite tendency of flights to the northeast.

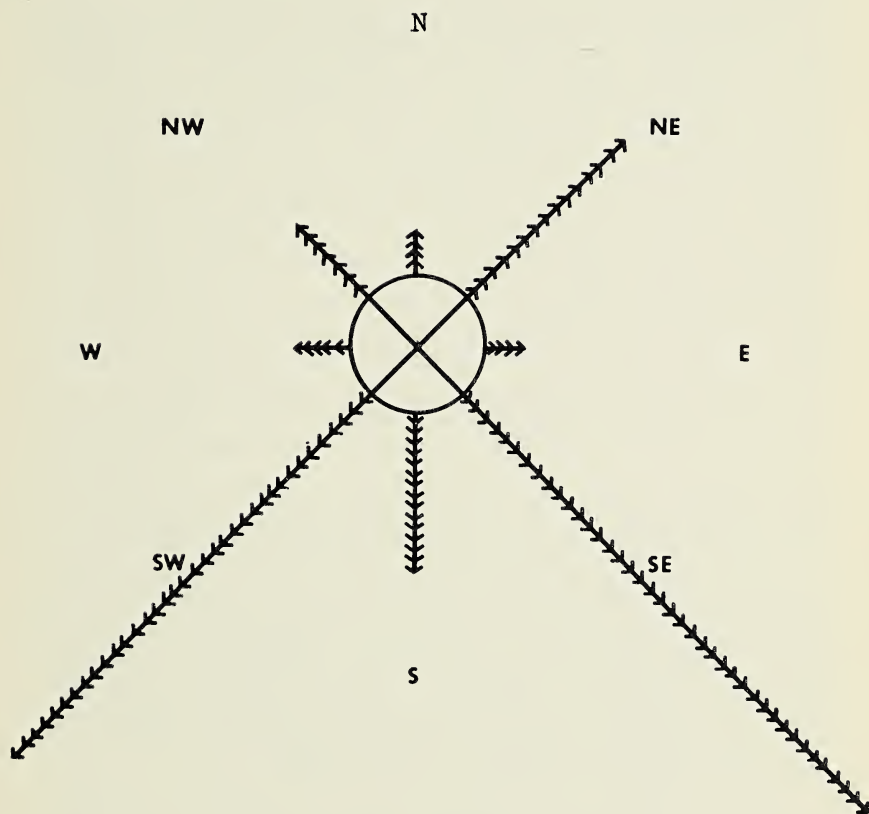


Fig. 4: Direction of migration of the entire population for the four year period of investigation. Explanation in text.

CONCLUSIONS

It would appear, as a result of this study and previous ones, that the monarch butterfly exhibits two types of movement; one extending over long distances as is the case for the Eastern North American Population (Urquhart op. cit.) and others in which the movement is restricted to shorter distances.

Of those that migrate over long distances, as from the eastern parts of the United States and eastern Canada to southern Mexico with a partial return migration, the females enter a period during which no eggs are produced by the ovaries — an ovarian dormancy (Urquhart op. cit.). During the autumnal flight southward such long-distance migrants collect on over-night roosting sites. On certain over-wintering sites, such as occur in the Monterey Peninsula of California, they remain throughout the winter months, (December to February) with no indication of ovarian activity (Urquhart op. cit.). Under laboratory conditions such females taken from the over-night roosting sites or from the over-wintering roosting sites fail to lay eggs. In contrast, the offspring from gravid females collected at the same time as the long-distance migrants were moving southward, continue to lay eggs throughout the winter months. Or, if females are collected during the early summer and mid-summer period, eggs will be laid and the offspring continue to do so throughout the winter months (Urquhart and Stegner op. cit.).

Of those that migrate over short distances, as in the case under consideration, there is no ovarian dormancy and they do not cluster on roosting sites. However, as indicated in this study, the movements do coincide in time with those of the long-distance migrants of the Eastern North American Population—eg. a northeasterly trend in the spring and early summer and a southerly trend in the late summer and fall.

One can hypothesize a definite advantage to an ovarian dormancy for long-distant flights. There would be less delay caused by oviposition. There would be less weight due to the absence of eggs. There would be more body fat available for longer flights. There would be a longer life period, extending up to six months (September to March) — gravid females on depositing their full complement of eggs live a much shorter time and it has been observed in our laboratory colonies that once oviposition starts, the appendages become brittle resulting in the loss of tarsi with the resulting destruction of the chemoreceptors and hence the inability of the individual to locate the

source of food or indeed to be stimulated to oviposit; this process and the relationship between the chemoreceptor mechanism and food selection is now being investigated in our laboratory.

Ovarian dormancy occurs in over-wintering populations in northern California and in all of the other states of the United States and provinces of Canada with the exception of resident populations in southern California and southern Florida. It is interesting to note that all of North America, with the exception of southern Florida and southern California, has diurnal temperature fluctuations that repeatedly reach freezing or near-freezing conditions from November through April with marked fluctuations in late September and October. This variation in diurnal temperatures can be correlated with the passage of cold fronts as a result of polar air mass outbreaks from the northwest (Urquhart op. cit.). Cold fronts rarely affect southern California and hence freezing temperatures are not frequently experienced there. A few examples of average monthly variations for Los Angeles are as follows: September 75° -59° F.; October, 72° -55° F.; January and February, 63° -43° F. A similar situation, with a tendency to higher maxima, occurs in Florida.

From the above it would appear that ovarian dormancy is correlated with marked fluctuations in diurnal temperatures in which the lows repeatedly reach freezing or near-freezing conditions. Such fluctuations are effective in the larval stage producing an ovarian dormancy in the adult females. In the absence of such marked fluctuations ovarian dormancy does not occur and breeding becomes continuous, assuming the presence of the host plant. This proposal would also explain the reason why no ovarian dormancy is experienced in the laboratory where temperatures are fairly constant throughout the year (72° F.). Similarly, ovarian dormancy was absent in specimens reared in the greenhouse where light period was the same as that out-of-doors.

It has been noted that the population under consideration exhibits movement to the southeast and southwest with a few direct southerly flights. This peculiarity fits the same pattern applicable to the Eastern Populaion (Urquhart op. cit.). To account for this tendency, one may propose the following explanation: That a positive phototaxic response would account for the southeasterly movement in the a.m. period and southwesterly movement in the p.m. period with only a slight south

movement during the short meridian period. This conception is indicated in laboratory observations in which butterflies congregate at the section of the cage where the light is most intense; thus in the a.m. period they congregate in the southeast section and in the p.m. period in the southwest section.

It is probable that many species of insects that are not considered migrants, although sight observations would indicate movement, follow a pattern similar to that discussed in this study. Thus, movements tend to be directional at one time of the year and not at another, which may occur during the breeding season for those species which do not possess an ovarian dormancy period. By utilizing the marginal alar tag system for the larger species of Lepidoptera it might be found that those species which are suspected of being long-distant migrants follow a similar pattern. There are periodic migrations over long distances by various species of Lepidoptera in which one would suspect a similar pattern on a restricted basis during most years, but with a definite trend over long distances at other times. Our studies are now being expanded to include the movements of other species of Lepidoptera, employing the alar tag system.

SUMMARY

The marginal alar tag system for following the movements of individuals of a population was employed to find out whether or not members of a continuously breeding population showed a tendency to migrate. It was found that a restricted migration did take place and that the direction and time of movement followed the same sequence as the eastern North American population that has been shown to travel great distances. The continually breeding population was compared to one possessing an ovarian dormancy period. It was suggested that this dormancy period permitted longer flights because of increased longevity, time saved by not ovipositing, decreased weight and the availability of stored fatty material. A correlation between low temperature fluctuations in late summer and fall and ovarian dormancy was indicated. It is suggested that perhaps other species of insects follow a similar flight pattern to that discussed in the present study and that in so far as the larger species of Lepidoptera are concerned, the use of the marginal alar tag system might give definitive data upon which an accurate analysis could be made rather than an analysis based on slight records. It is further suggested that, although movement on the

part of a species may be over a short distance the number of individuals taking part may vary with seasonal changes, particularly in the case of unusually long periodic flights.

ACKNOWLEDGMENTS

We are indebted to Mr. J. T. Carlisle of Whittier, California who was responsible for rearing, tagging and reporting on a large percentage of the population studied.

This investigation, which is a small part of a much larger study dealing with the ecology and physiology of *Danaus plexippus* was made possible by grants to the University of Toronto from the National Research Council of Canada and the National Geographic Society.

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HABITAT — *Zerene caesonia eurydice* Bdv.



This, the Dog's Head butterfly, is found typically from Mendocino and Sonoma counties in California into Baja California. *Z. c. caesonia* is found from the Great Lakes region to Argentina, in North America from southeastern California to the Atlantic. *Z. c. eurydice* should be considered a local offshoot, or geographic race, isolated along the coast of California where it occurs closely in connection with its larval foodplant, *Amorpha californica*. There is no indication that any other plant will suffice for long as the larval foodplant.

(continued on page 190)

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THE EFFECT OF PTERIN PIGMENTS ON WING COLORATION OF FOUR SPECIES OF PIERIDAE (LEPIDOPTERA)

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THE PTERINS ARE A CLASS of chemical compounds with a widespread but sporadic distribution throughout the animal kingdom. They were first isolated from pierid butterflies where they are responsible for the orange, yellow and white coloration of the wings. Although the Pieridae are the only butterflies from which pterins have been reported, these pigments have been identified in representatives of other insect orders and in crustaceans. Pterins have also been reported from certain fish, amphibians, reptiles and mammals (Fox and Vevers, 1960).

The first major study of pterins was undertaken by F. Gowland Hopkins (1895), who extracted these white, yellow and red pigments from various Pieridae. At the time, he did not realize he was working with an entirely new class of chemical compounds. In fact, he identified the white pigment as uric acid and stated that the yellow and red pigments were close relatives of uric acid. By means of more refined chemical tests, it is now known that the pigments Hopkins extracted were indeed pterins.

The object of this study was to extract and identify the wing pterins of several species of pierids and to determine if there was any correlation between wing color and pterin content. The four species finally chosen for intensive study included the white *Pieris rapae* (Linnaeus), the yellow *Colias harfordii* H. Edwards, the yellow-orange *Colias eurytheme* Boisduval, and the orange *Eurema nicippe* (Cramer).

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Table I

R_T values for pterins.

	<u>Xantho</u>	<u>Isoxantho</u>	<u>Erythro</u>	<u>Leuco</u>	<u>Sepia</u>
<u>P. rapae</u>					
Propanol	.14	.14	.06	.06	.39
Butanol	.35	.22	.10	.08	.35
<u>C. harfordii</u>					
Propanol	.14	.14	.03	.05	.35
Butanol	.34	.23	.09	.08	.34
<u>C. eurytheme</u>					
Propanol	.13	.13	.03	.05	.35
Butanol	.35	.22	.09	.08	.35
<u>E. nicippe</u>					
Propanol	.13	.13	.03	.05	.35
Butanol	.32	.22	.08	.06	.32
Standards					
Propanol	.15	.17	.05	.07	---
Butanol	.30	.19	.08	.07	---

The pterin pigments from the four wings of a dried specimen were extracted with 2 ml of 1% ammonia after washing the wings in about 10 ml of acetone. The pigments were then applied to Whatman No. 1 chromatography paper, the spots being about 2-3 mm in diameter. The chromatograms were developed by means of descending paper chromatography using 7:3 propanol/1% ammonia and 4:1:1 butanol/acetic acid/water as solvents. The solvent front was allowed to advance about 15 cm on the paper. The chromatograms were then removed from the chromatography tank and dried with a hair drier. The pterin spots were located under long-wave ultraviolet light and identified by their characteristic fluorescing colors and R_F values.

Standards were established by chromatographing known pterins (isoxanthopterin and erythropterin from Aldrich Chemical Co.; xanthopterin and leucopterin from K and K Laboratories). A small quantity of each standard was dissolved in a few ml of 1% ammonia and run separately, according to the procedures outlined above.

RESULTS

In Table I the average R_F values obtained for the pigments of the four species of Pieridae are compared with those obtained for the standards. The values represent averages compiled from the results of a large number of chromatograms. Table II compares the UV fluorescing color with the actual color of the pigments. Using both R_F values and fluorescing colors, it was found that each species of Pieridae contained the same five pigments.

DISCUSSION

Watt (1964) also characterized the pterin pigments of *Colias eurytheme*. Table III compares my results with those of Watt and in addition shows the R_F values for the standards. All determinations were made using 4:1:1 butanol/acetic acid/water and Whatman No. 1 paper. I was unable to obtain a standard of sepiapterin, but the R_F value and color of fluorescence observed for this unidentified spot agree very closely with the literature for that of sepiapterin (Harmsen, 1966; Watt, 1964).



Figures 1-4. 1. *Pieris rapae*, 2. *Colias harfordii*, 3. *Colias eurytheme*, 4. *Eureka nicippe*. The upper specimen (minus the body) in each figure shows the typical phenotypic coloration of the species. The lower specimen shows the effect of removing the wing pterins. In each case the lower specimen has a pearly lustre which is due entirely to a structural effect. When the



pterins are removed the scales are not affected and the reflected light gives the white appearance. The dark color that is found on the wings as spots and/or marginal bands is due to the presence of melanin. The melanin is insoluble in 1% ammonia and therefore is not extracted with the pterins.

Table II

Color of pterins.

<u>Pigment</u>	<u>UV</u>	<u>Visible</u>
Xanthopterin	Yellow-Green	Yellow
Erythropterins	Reddish-Orange	Red
Isoxanthopterin	Bright Blue	White
Leucopterins	Pale Blue	White
Sepiapterin	Yellow	Yellow

Table III

R_F values for pigments of *C. eurytheme* and standards.

	<u>Xantho</u>	<u>Isoxantho</u>	<u>Erythro</u>	<u>Leuco</u>	<u>Sepia</u>
Standard	.30	.19	.08	.07	---
1	.33	.21	.11	.07	.33
2	.35	.22	.09	.08	.35

All four species of Pieridae were shown to contain the same five pterin pigments but in varying amounts. By assuming a correlation between strength of fluorescence and amount of pigment present, the relative quantities of each pigment could be estimated. *P. rapae* contained large amounts of isoxanthopterin and leucopterin and smaller amounts of the other three pigments. *C. harfordii*, *C. eurytheme* and *E. nicippe* contained lesser amounts of the white pigments and large amounts of the yellow pigments, especially xanthopterin. The largest amounts of erythropterin were detected in *E. nicippe*.

It can then be concluded that in this representative sample of pierids, the whites, yellows, and oranges of the wings are due to the differential concentration of certain pterins.

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HABITAT — *Zerene caesonia eurydice* Bdv.



(continued from page 182)

Amorpha californica occurs from sea level to 8000 feet in elevation. The habitat shown (Fig. 1) is at 6500 feet in the Mill Creek Canyon, San Bernardino Mountains, California, taken May 31, 1970. Here *Zerene* is present in a highly variable population, mostly in the forms known as *eurydice* but with a continuous range of variability to *caesonia*. *Amorpha* are the bushes, ranging from one to four feet high, shown around the rocks (Fig. 1). A plant is shown in closer view in Fig. 2.

W. Hovanitz

HILLTOPPING AS A MATING MECHANISM TO AID THE SURVIVAL OF LOW DENSITY SPECIES

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INTRODUCTION

HILLTOPPING INSECTS HAVE BEEN REPORTED to be rare by Catts (1964), Chapman (1954), Dodge & Seago (1954), and Hagen (1962), but no evidence has appeared for Lepidoptera. The purpose of this paper is to describe the difference in density of two groups of butterflies and skippers from Gregory Canyon, Boulder County, Colorado, those species which show hilltopping behavior and those without this behavior, and to give possible explanations why hilltopping species are rare. Mating mechanisms other than hilltopping are also discussed. General characteristics of hilltopping species are given.

HILLTOPPING DEFINED AND EXAMPLES OF HILLTOPPING

Hilltopping is defined as a behavior of certain insects in which males fly to the summits of hills and when there remain on the summit and show perching ("territorial") behavior or patrolling behavior, resulting in an unexpected abundance of males on hilltops. This is a behavioral definition; thus the distribution of males on hilltops is independent of the distribution of the foodplant. The foodplant may be only on the hilltop, or it may be a half mile away. Males may either perch on a shrub or spot of ground (for instance, *Papilio zelicaon*, Shields, 1968) or may "patrol" back and forth on the summit (Shepard, 1966, for *Pieris occidentalis*). Both types of behavior were noted by MacNeill (1964) in non-hilltopping situations for males of *Hesperia* ("occupation" behavior by *H. comma* and patrolling by *H. lindseyi*), so it is evident that hilltopping behavior is not fundamentally different from non-hilltopping behavior; hilltopping behavior occurs when these activities are transferred to a hilltop. Perching males may remain on a hilltop for several days; Shields (1968)

Table 1. Results of six hours of collecting on two hilltops within one mile of Gregory Canyon (the tops of Flagstaff and Green Mountains), showing the number of specimens caught and the difference between the abundance of these species on the two hilltops sampled and the abundance of the same species in Gregory Canyon. The hilltopping species increased an average of .91 specimens/hour on hilltops, while the non-hilltopping species decreased an average of 1.00 specimens/hour on the hilltops. (*data from Tables 2 & 3).

A. Hilltopping species			Abundance	Abundance	Difference
	male	fem.	on hilltops	in Gregory Can.*	
<i>Erynnis persius</i>	20		3.33	.61	2.72
<i>E. pacuvius</i>	4		.67	.14	.53
<i>E. martialis</i>	4	1	.83	.26	.57
<i>E. afraanius</i>	3		.50	.80	-.30
<i>Papilio zelicaon</i>	14	1	2.50	.051	2.45
<i>P. indra</i>	2		.33	0	.33
<i>P. rutulus</i>	1	1	.33	.16	.17
<i>P. eurymedon</i>	5		.83	.63	.20
<i>Pieris sisymbri</i>	6		1.00	.17	.83
<i>Oeneis chryxus</i>	15		2.50	.24	2.26
<i>Speyeria callippe</i>	9		1.50	.18	1.32
<i>S. edwardsii</i>	4		.67	.12	.55
<i>Vanessa atalanta</i>	1		.17	0	.17
means			1.17	.26	.91
B. Non-hilltopping species					
<i>Coenonympha tullia</i>	1		.17	2.47	-2.30
<i>Oeneis uhleri</i>	2		.33	1.81	-1.48
<i>Callophrys apama</i>	2		.33	1.91	-1.58
<i>C. polios</i>	2		.33	1.26	-.93
<i>Celastrina argiolus</i>	7	9	2.67	1.40	1.27
means			.77	1.77	-1.00

recaptured marked *P. zelicaon* up to a month after release. Some species may visit hilltops only once, however, since of 46 *Vanessa cardui* males that Shields released on a summit, none were recaptured after more than a day. Hilltopping *Pieris occidentalis* do not stay long in any area (Shepard, 1966).

A "hilltopping species" is defined as a species which has been observed to show hilltopping behavior. Likewise, a non-hilltopping species is a species which does not show hilltopping behavior in the localities the author has studied. A rigid black-and-white separation of butterflies into hilltopping and non-hilltopping species is somewhat artificial; for some species of *Hesperia*, *Erynnis*, and *Papilio zelicaon*, hilltops probably serve as the primary site of mating, but for other species, such as *Speyeria* and *Ochlodes sylvanoides*, hilltops are probably minor. *Ochlodes sylvanoides* males perch on bushes in clearings both on hilltops and on flat areas. Nevertheless, this separation is presently justifiable until more is known about each species. *Papilio zelicaon* will serve as an example of a hilltopping species. In the spring of 1966 only one male and two females were caught in Gregory Canyon during almost sixty hours of collecting, but in one short trip to the top of Green Mountain (about one-half mile from Gregory Canyon) eight male *P. zelicaon* were caught in less than two hours. The males fly in rather fixed paths around the rock and through the trees on the summit; if missed, specimens usually return a few minutes later. Table 1 show the results of a brief period of collection on two hilltops near Gregory Canyon. The proportion of hilltopping species present, 13 out of a total of 18, was 72%, whereas it was 42% in Gregory Canyon where there are no hilltops. The densities of hilltopping species and nonhilltopping species were 1.17 and .77 respectively on the hilltops, while the densities for the same species in Gregory Canyon were .26 and 1.77.

GREGORY CANYON

During the spring of 1965, 1966, and 1967, the author made extensive collections of butterflies and skippers in Gregory Canyon, Boulder County, Colorado, a small foothills canyon on the eastern slope of the Front Range. It is less than a mile in length. The southern wall is covered with dense Douglas fir forest which is for the most part unsuitable for butterfly flight. The south-facing side of the canyon is a grassy slope with scattered ponderosa pines. In the bottom of the canyon is a variety of riparian shrubs and trees. Extensive collecting was done on the bottom and south-facing slope of the canyon, on the eastern slope of

Table 2. The abundance of nonhilltopping butterflies and skippers in Gregory Canyon.

Species	Dates of Captures	Specimens per hour
<i>Amblyscirtes vialis</i> (Edwards)	4-v to 30-v	.20
<i>A. aenus</i> Edwards	16-v to 30-v	.15
<i>A. osleri</i> (Skinner)	13-v to 30-v	2.06
<i>Euphyes vestris</i> (Boisduval)	28-v	4.00XX
<i>Poanes taxiles</i> (Edwards)	30-v	.33XX
<i>Polites themistocles</i> (Latreille)	29-v to 30-v	1.40
<i>P. mystic dacotah</i> (Edwards)	29-v	.14XX
<i>Oarisma garita</i> (Reakirt)	24-v to 30-v	3.37
<i>Pholisora catullus</i> (Fabricius)	16-v to 24-v	.39
<i>Pyrgus ruralis</i> (Boisduval)	2-v to 13-v	.11
<i>Epargyreus clarus</i> (Cramer)	19-v to 30-v	.33
<i>Papilio multicaudata</i> Kirby	5-v to 29-v	.18
<i>Colias alexandra</i> Edwards	29-v	.14XX
<i>C. philodice</i> Godart	27-iii to 24-v	.38
<i>Anthocaris sara julia</i> Edwards	14-v to 30-v	.10
<i>Coenonympha tullia ochracea</i> Edwards	5-v to 30-v	2.47
<i>Oeneis uhleri</i> (Reakirt)	26-iv to 23-v	1.81
<i>Euptoieta claudia</i> (Cramer)	29-v	.14X
<i>Phyciodes campestris camillus</i> Edwards	13-v to 30-v	.62
<i>P. tharos</i> (Drury)	13-v to 30-v	.41
<i>P. pallida</i> (Edwards)	19-v to 29-v	.62
<i>Nymphalis antiopa</i> (Linnaeus)	13-iii to 27-iii	.76
<i>Polygonia zephyrus</i> (Edwards)	13-iii to 23-v	.67
<i>P. satyrus</i> (Edwards)	14-iv to 28-iv	.11
<i>Limenitis wiedemeyeri</i> Edwards	29-v	.14XX
<i>Callophrys polios</i> (Cook & Watson)	27-iii to 23-v	1.26
<i>C. erephon</i> (Boisduval)	30-iii to 24-v	1.12
<i>C. fotis schryveri</i> (Cross)	30-iii to 5-v	.40
<i>C. apama homoperplexa</i> Barnes & Benjamin	14-iv to 30-v	1.91
<i>C. sheridanii</i> (Edwards)	26-iii to 15-v	.81
<i>Plebejus melissa</i> (Edwards)	5-v to 30-v	.40
<i>P. acmon lutzii</i> dos Passos	13-v to 23-v	.071
<i>P. icarioides lycea</i> (Edwards)	14-v to 30-v	4.24
<i>Glaucopsyche lygdamus oro</i> Scudder	15-iv to 29-iv	2.74
<i>Scotitantides piasus daunia</i> (Edwards)	14-v to 30-v	1.36
<i>Everes comyntas valeriae</i> Clench	2-v to 30-v	.56
<i>Philotes enoptes ancilla</i> Barnes & McD.	5-v to 30-v	.68
<i>Celastrina argiolus cinerea</i> (Edwards)	14-iv to 30-v	1.40

mean 1.034

s = 1.028

XX-data thrown out because less than
ten hours of collecting

Flagstaff Mountain and on the north slope of Chautauqua Mesa, both grassy hillsides with a variety of herbs, at the mouth of the canyon. Brief collecting results on the tops of two nearby hills, Flagstaff Mountain and Green Mountain are compared with results in Gregory Canyon.

METHODS

To find out if hilltopping is more prevalent among the rarer species, the densities of butterfly species in the localities outlined above were studied. Average density is defined in this study as the total number of individuals of each species divided by the total number of hours spent collecting in the area during the flight period of the species under consideration. For instance, *Amblyscirtes oslari* was collected in Gregory Can. from May (v) 13 to May 30. Since 110 specimens were taken in the canyon during this time span, and a total of 53.5 hours were spent collecting in the canyon on and between May 13 and 30, the density is $110/53.5$ or 2.06 spec./hour. It can be seen that this abundance value measures neither total population size nor density, but is an estimate of average density over the total area during the flight period. Since the flight periods of many species were much greater than those of other species, the ratio of specimens per hour was preferred to the number of specimens as an indicator of relative density since it measures the average density of a particular species during the flight period sampled. However, in the statistical test below, both methods of measuring the density were used, and produced similar results. The densities for each species are in Tables 2 and 3. Data for species with less than 10 hours of collecting are unreliable and were not used in the statistical tests. Species with less than 10 hours of collecting were usually those just beginning their flight period at the end of May; thus the number of specimens collected may not represent the abundance later on in the flight period.

Several criticisms of this type of method for sampling the density are pertinent. First, it is very crude. It would be best to have sampling programs for each species or run mark-release studies for each species to estimate the population size. These studies are impossible for the large number of species considered, and it is necessary to study large numbers of species to minimize the effect of "abnormal" species in making generalizations about hilltopping and nonhilltopping species. Second, the collector could be prejudiced in sampling. An attempt was made to collect everything flying. Since the species likely to be undercollected are the common species in most instances, prejudiced collecting

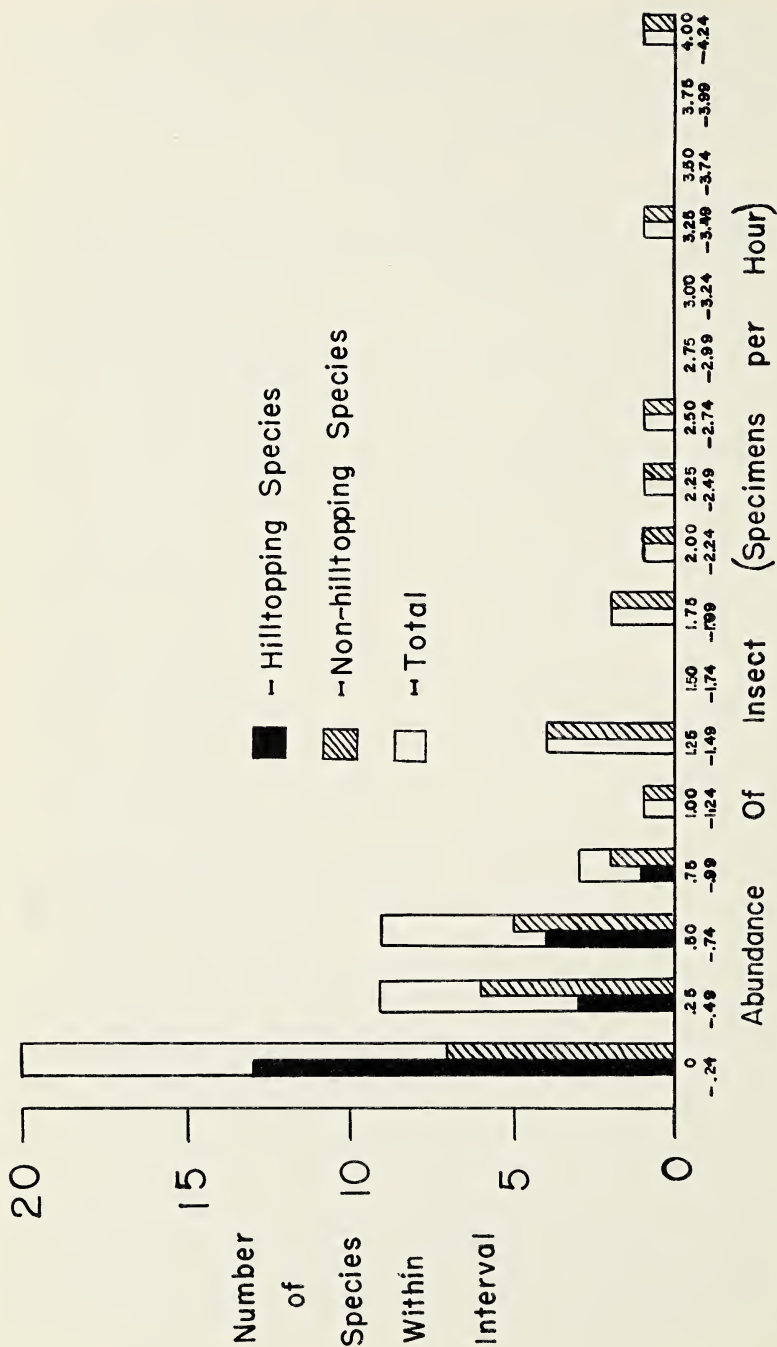


Figure 1. Abundance of butterflies in Gregory Canyon, 1966.

would shift the results so that the less abundant species would appear to be more common. The results actually obtained, that the hilltopping species are less abundant, are thus not affected. An attempt was also made to collect the area uniformly. The area was sampled by walking across the lower slopes of Chautauqua Mesa to the southeastern slope of Flagstaff Mountain, and then proceeding up Gregory Canyon along a trail near the stream bottom. The south-facing slope of the canyon was traversed, and the route then reversed. Varying amounts of time were spent each day depending upon weather conditions, etc. Collecting was done between 9 a.m. and 5 p.m., usually between 10 and 4. A third criticism is whether the year or the locality is unusual, resulting in abnormal abundance of certain species. Every locality of course varies in the abundance of certain species, but since the number of both hilltopping and non-hilltopping species is fairly large, the average abundance figures of the two groups are assumed to be not unduly affected by abnormal abundance values.

ABUNDANCE OF HILLTOPPING VERSUS NONHILLTOPPING SPECIES

The results are shown in Tables 2 and 3 and are graphed in Figure 1. 2023 specimens were collected. The average values for the number of specimens per hour were found to be .28 for the hilltopping species and 1.03 for the nonhilltopping species. Thus the hilltopping species are one fourth as dense on the average as the nonhilltopping species. The variations in density within each group was great, with standard deviations of .23 and 1.03 for hilltopping and nonhilltopping groups respectively, and the groups overlapped considerably. The second lowest density was recorded for *Plebejus acmon*, a non-hilltopping species, and the fifteenth highest density was recorded for *Erynnis lucilius*, a hilltopping species. But in only 6 of 21 species of hilltopping butterflies was the value above .26, and in the non-hilltopping species only 7 of 32 had values .32 or below. A test of the hypothesis that there is no difference in density of the hilltopping and non-hilltopping groups is shown in Table 4. The probability that the results obtained are due to chance is .002 (Fisher's exact method). Another test of the hypothesis that there is no difference in the absolute number of specimens caught of hilltoppers and non-hilltoppers resulted in a probability of .008 that there is no difference.

Table 3. The abundance of hilltopping butterflies and skippers in Gregory Canyon, 1966.

Species	Dates of Captures	Specimens per hour
<i>Hesperia juba</i> (Scudder)	19-v to 29-v	.18
<i>Erynnis persius fredericki</i> Freeman	28-iv to 30-v	.61
<i>E. pacuvius</i> (Lintner)	1-v to 29-v	.14
<i>E. martialis</i> (Scudder)	1-v to 30-v	.26
<i>E. icelus</i> (Scudder & Burgess)	3-v to 24-v	.26
<i>E. lucilius afranius</i> (Lintner)	27-v to 30-v	.80
<i>E. telemachus</i> Burns	3-v	.25XX
<i>Thorybes mexicana nevada</i> Scudder	25-v to 30-v	.093
<i>T. pylades</i> (Scudder)	14-v to 30-v	.46
<i>Papilio zelicaon</i> Lucas	29-iv to 28-v	.051
<i>P. indra</i> Reakirt	25-v to 28-v	0**XX
<i>P. rutulus</i> Lucas	28-v to 30-v	.16
<i>P. eurymedon</i> Lucas	19-v to 29-v	.63
<i>Euchloe olympia rosa</i> (Edwards)	1-v to 13-v	.083
<i>E. ausonides coloradensis</i> (H. Edwards)	14-iv to 30-v	.63
<i>Pieris sisymbri elivata</i> Barnes & Benj.	14-iv to 28-v	.17
<i>Oeneis chryxus</i> (Doubleday)	23-v to 30-v	.24
<i>Speyeria callippe meadi</i> (Edwards)	24-v to 28-v	.18
<i>S. edwardsii</i> (Reakirt)	25-v to 30-v	.12
<i>S. coronis halcyone</i> (Edwards)	29-v	.14XX
<i>Poladryas arachne</i> (Edwards)	27-v	.25XX
<i>Chlosyne ismeria carlota</i> (Reakirt)	24-v to 27-v	.14XX
<i>Nymphalis milberti furcillata</i> (Say)	13-iii to 2-v	.12
<i>Vanessa cardui</i> (Linnaeus)	15-iv to 15-v	.075
<i>V. atalanta</i> (Linnaeus)	28-v	0**XX
<i>Strymon melinus franki</i> Field	1-v	.17XX
<i>Callophrys spinetorum</i> Edwards	3-v to 13-v	.13
<i>C. augustinus irioides</i> (Boisduval)	26-iii to 4-v	.60
XX- data thrown out because less than ten hours collecting		mean .285 S = .231

** - specimens seen but could not be collected

POSSIBLE EXPLANATIONS FOR THE LOWER DENSITY OF HILLTOPPING SPECIES

Fewer specimens of hilltopping species could have been caught in the canyon because the males were on nearby hilltops. However, the percentage of males of 1957 total specimens for which the sex was determined was 74.2% (with 95% confidence limits of 53% and 86%) for hilltopping species and 82.6% (with 95% confidence limits of 66% and 96%) for nonhilltopping species. The greater number of males is not due to female mortality or actual skewed sex-ratios in the population at birth, since rearing butterflies usually results in equal numbers of males and females (Shields, 1968), but is probably due to more overt behavior on the part of the males; females are inconspicuous due to oviposition behavior. Therefore, the disparity in abundance is not explained by different sex-ratios or by the absence of males due to their flying to distant hilltops. Also, the two hilltops nearest to Gregory Canyon are relatively far from the collecting area, are 600 to 1500 feet higher than Gregory Canyon, and are comparatively poor in number of species and individuals present.

A hypothesis of the ecological function of hilltopping suggests that male butterflies are on hilltops for mating purposes. This theory suggests that males, which in butterflies usually emerge earlier than females, visually orient and fly to the hilltops and that the females, when they emerge, then fly to hilltops, mating occurs, and then the female leaves to lay her eggs. Presumably if the female meets a male before she arrives at a hilltop, mating would occur and she would then not visit a hilltop. This theory is supported by observations of mating pairs on hilltops, a high percentage of virgin females of hilltopping species on hilltops, and an experiment in which virgin female *Papilio zelicaon* flew to hilltops (Shields, 1968). However, no studies have been conducted which compare the number of matings [or percent virgins] on a hilltop with the number [or percent] off a hilltop.

This theory suggests several reasons why hilltopping species should be less dense than non-hilltopping species.

Hilltopping may provide a rendezvous for very rare species which otherwise may not produce enough individuals to survive. In general the number of contacts between individuals should be proportional to the density of the population; in low-density populations a hilltop rendezvous may increase contacts to the extent that the percent of females which successfully mate is not

Table 4. Contingency tables of the abundance of the species.

Figures above slash refer to number of species above or below mean (.737 specimens per hour) using the number of specimens per hour as an indicator of abundance. Figures below slash refer to number of species above or below mean (37.96 specimens) using the number of specimens caught as an indicator of abundance. Probabilities that tables as or more extreme than the ones above occur by chance alone are .002 using number of specimens per hour, and .008 using total number of specimens (Fisher's exact method).

	No. of species with abundance greater than mean*	No. of species with abundance less than mean*	Totals
Hilltopping Species	1/ 2	20/ 19	21
Non-hilltopping Species	14/ 15	18/ 17	32
Totals	15/ 17	38/ 36	53

seriously reduced. A nonhilltopping species in a marginal locality where it is rare may not survive. This may be the reason why most hilltopping species are widespread and less dense, which many nonhilltopping species are local and dense.

Hilltopping can be effective only for low density species, because 1) at high densities on hilltops interference between males prevents mating with females, and 2) the number and area of hilltops is limited. Point 1) is based on the author's and Shields' (1968, pp. 134, 139) observations. Point 2) is supported below. If a species is common, only a small proportion of the males can occupy a hilltop, so that most males will be forced into nonhilltop situations. As population density rises, the probability that a female will meet a male before reaching a hilltop therefore increases, so that hilltopping is less important for commoner species. The few males on hilltops could not possibly inseminate all the females in a common species, so that most matings will occur with males which remain at the breeding site or which are between the breeding site and the hilltop. Because hilltopping is less useful for common species, selection should eliminate the hilltopping response since males which remain at the breeding sites will contribute more genes to the next generation.

It is possible that hilltopping could act as a "population control" agent to prevent the population from exceeding a certain density. However, the author's preliminary data for *Hesperia pahaska* and *Amblyscirtes simius* indicates that hilltopping breaks down when these species are dense and mating occurs on hill-sides and sloping ridges as well as hilltops.

Hilltopping may centralize the gene pool of a population. It is conceivable that this could reduce the density of the species in an area by preventing microenvironmental adaptation. This would be difficult to prove, and two different microhabitats within the dispersal range of a species may not exist .

CHARACTERISTICS OF HILLTOPPING SPECIES

Hilltopping species are in general large, fast-flying, solitary species with more widely scattered and less abundant foodplants than non-hilltopping species, which tend to be small, weak-flying, colonial species with common or clumped foodplants. The average size of hilltopping species is 22.6 mm in Gregory Canyon, while the size of nonhilltopping species is 17.5 mm (based on the average of the left front wing length of three males); this difference is significant at the 5% level. The average abundance

of the host plant is 1.89 for hilltopping butterflies, and 2.68 for non-hilltopping butterflies (based on a rating system from 1-rare to 5-abundant of known Gregory Canyon foodplants by the author); this difference is significant at the 1% level, although admittedly the system for rating the plant is imprecise. All of the hilltopping species in Gregory Canyon are "fast-flyers" with the exception of *Poladryas arachne*, whereas less than half of the species of non-hilltopping species fit into this subjective category. A hilltopping species must be highly motile, of course, to reach distant hilltops. Hilltopping is probably more prevalent in dry or sparsely vegetated mountainous areas, since more small hilltops occur in eroded foothill and chaparral regions than in flat areas, and few hilltopping males occur on densely forested hilltops.

OTHER MATING MECHANISMS

There are methods other than hilltopping of bringing the sexes together from a distance. These other mechanisms put hilltopping in proper perspective and are listed below. A fundamental difference between these mechanisms and hilltopping is that many males can participate in the following mechanisms whereas fewer males can fit on a hilltop; therefore the following mechanisms are operable at much higher densities. They may not be mutually exclusive.

1) Chemoreception is known to be very important in the long-distance location of females by males in moths, and in the courtship of moths and butterflies (Jacobsen, 1965). It may prove to be important in location of females by males in *Heliconius* (Edwards, 1881; Bellinger, 1954) and *Parnassius*. For most butterflies, however, the maximum distance of attraction is limited by sight, while chemoreception is important only within a few meters of the female by the release of pheromones from hair pencils, androconial scales, etc.

2) Foodplant congregation. Most butterflies, especially the weak-fliers, spend their entire lives, except for brief forays in search of mud or flowers for nourishment, around stands of the foodplant, and therefore have a built-in mechanism for bringing the sexes together. Often both sexes are limited both to foodplant and to certain areas of the environment such as rockslides (*Erebia magdalena*), bogs (*Boloria frigga*), or freshwater springs (*Speyeria nokomis*), which may or may not be the only locations of the foodplant. The behavior of these species usually limits them to these areas so that mating is possible with "random" flight by both sexes or by patrolling of the area by males as in

Boloria (J. Shepard, unpublished).

3) In some species the males occupy small areas along the bottom of a gully or canyon, presumably for mating purposes. Males may occupy an area for some time, but this behavior may not be territorial since the males may wander to another gully and show the same behavior. Butterflies which show this behavior are *Polygonia*, *Euptychia*, *Callophrys apama*, *Papilio rutulus*, and *Amblyscirtes oslari*. The author conducted mark-release studies in Gregory Canyon in 1967. 40 *C. apama* males were marked and released in a small gully, and of these 13 were recaptured, including three which were recaptured twice each, and individuals which were recaptured at the same spot after 2, 5, 5, 9, 19, and 19 days. 46 male *Polygonia zephyrus* were released, and 7 were recaptured, including males which were recaptured after 1, 8, 9, 9, 10, 13 days. One individual moved a distance of 1000 feet and then was recaptured, then moved a distance of 200 feet before being recaptured again; all others were recaptured near the place of release. *Amblyscirtes oslari* males show this type of behavior in roadside ditches and small gullies.

SUMMARY

Hilltopping species appear to be a heterogeneous taxonomic and behavioral assemblage. They are characterized by the transference of mating behavior to hilltop situations. The behavior of *Papilio zelicaon* and *Hesperia pahaska*, in which the males perch on hilltops, is similar to the behavior of *Polygonia zephyrus* and *Amblyscirtes oslari*, non-hilltopping species in which the males perch in gullies. By contrast, the behavior of *Pieris occidentalis*, a hilltopping species in which males patrol the summit, is quite different. A separation of butterfly species into two groups, namely, those in which males perch, and those in which males continually fly in search of females (patrol), is a more widely applicable classification of their mating behavior.

Hilltopping species have many traits in common, however. They do not congregate about the foodplant but instead tend to be large, strong-flying, solitary species with more widely scattered foodplants than other species. Populations of hilltopping species are less dense than those of other species since selection favors the development of hilltopping in low density species, but hilltopping confers little or no advantage to species with high numerical density. Common species would benefit from hilltopping only when their populations fall to low levels.

Hilltopping may be selected for at low population levels, and remaining near the foodplant may be selected for at high levels, so that the advantage of hilltopping for a particular species depends on its average density and the fluctuations from this average.

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NOTICES

BOOKS:

BUTTERFLIES. A concise guide in colour. Josef Moucha, ill. by Vlastimil Choc. Paul Hamlyn, Hamlyn House, The Centre, Feltham, Middlesex. G.B.

BIOGEOGRAPHY OF THE SOUTHERN END OF THE WORLD. Philip J. Darlington, Jr. McGraw Hill paper back reprint, N.Y.

THEORIES ON THE NATURE OF LIFE. Giovanni Blandino, S.J. Philosophical Library, N.Y.

INTRODUCTION TO ZOOLOGY. Theodore H. Savory. Philosophical Library, N.Y.

WANTED:

Brephidium exilis, *B. fea*, *B. isophthalma*. Life material and specimens for distribution study. Roy Jameson, 2429 Wordsworth, Houston, Texas 77025.

ARGYNNIS. Local and world wide, for world biogeographic study. Also related forms under whatever name. William Hovanitz, 1160 W. Orange Grove Ave., Arcadia, California 91006.

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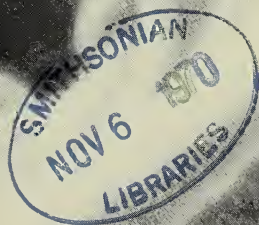
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SCANNING ELECTRON MICROSCOPY ON WING SCALES OF *COLIAS EURYTHEME*

JOHN M. KOLYER AND ANNEMARIE REIMSCHUESSEL

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OPTICAL MICROSCOPY DISCLOSES that the scales on the wings of Lepidoptera may be ribbed lengthwise, with perpendicular cross-ribs to give a network (Gentil, 1935), but finer details cannot be resolved. Transmission electron microscopy has been utilized to study the fine structure of *Morpho* scales (Gentil, 1942; Kinder and Süffert, 1943; Richards, 1944), whose iridescent colors are "structural" and result from diffraction of light by ridges on the scale rather than from the presence of pigments. However, in the family Pieridae, including the genus *Colias*, the yellow and/or orange colors are not structural, and transmission electron microscopy has been reported to disclose round and spindle-shaped aggregations of pigment (Yagi, 1954), which consists of a number of pteridine compounds (Watt, 1964). The black scales in the border are colored by melanins.

The present work was undertaken on the premise that the recently-developed method of scanning electron microscopy (SEM) should be particularly well-suited, due to its advantageous magnification range (45-30,000 X) and depth of focus, to examination of the surface structure of the scales. *Colias eurytheme* (Boisduval) was chosen as an example. A particular object was to note possible variations in the fine structure of scales from different areas of the wing.

METHODS

Figure 1 shows a specimen, male, with indication of the areas examined. Small portions of these areas were cut out with a scalpel, and each was mounted on a specimen stub. The specimens were vapor-coated with a thin (300 Angstroms) layer of gold/palladium alloy (60/40) to render them conductive, a prerequisite for examination by SEM. The SEM instrument was a JEOLCO JSM-2, operated at an accelerating voltage of 25 kv. Photomicrographs were prepared with Polaroid P/N Type 55 film at a scan speed of 50 seconds per frame.

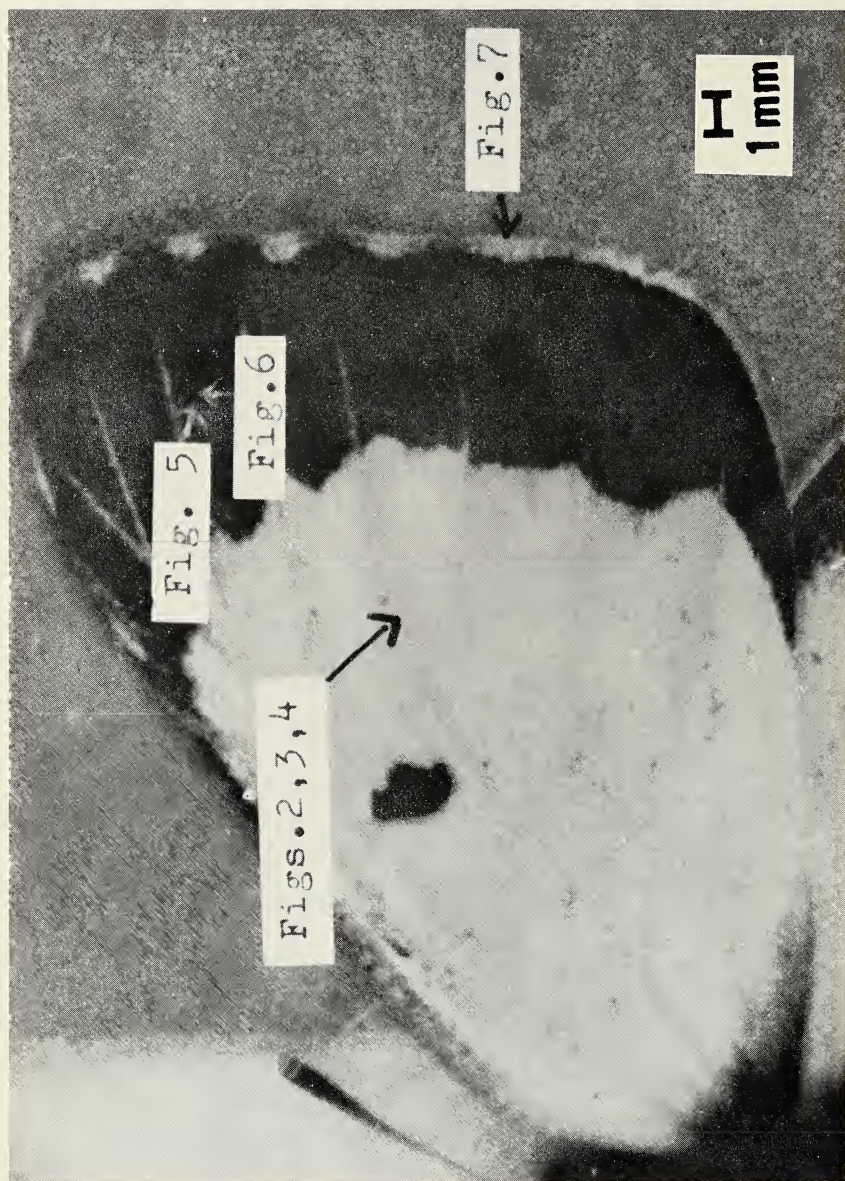


Fig. 1.—*Colias eurytheme*, male. Right forewing, showing location of scales examined.

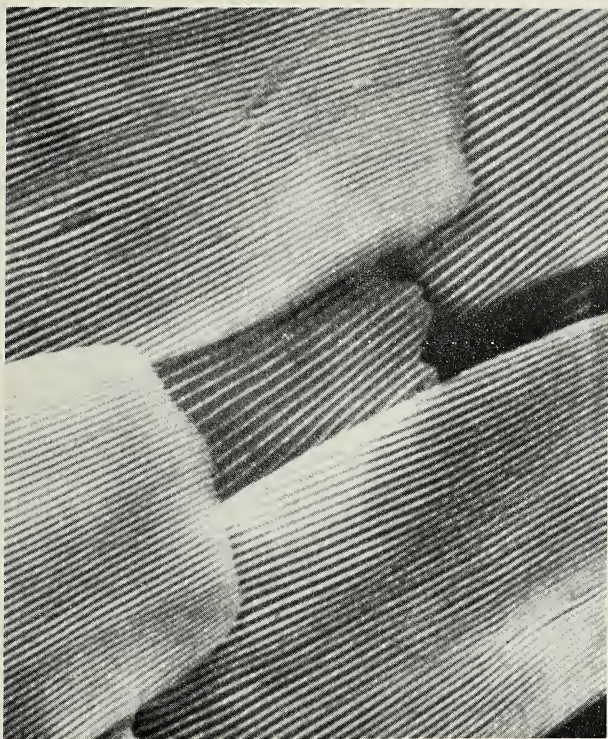
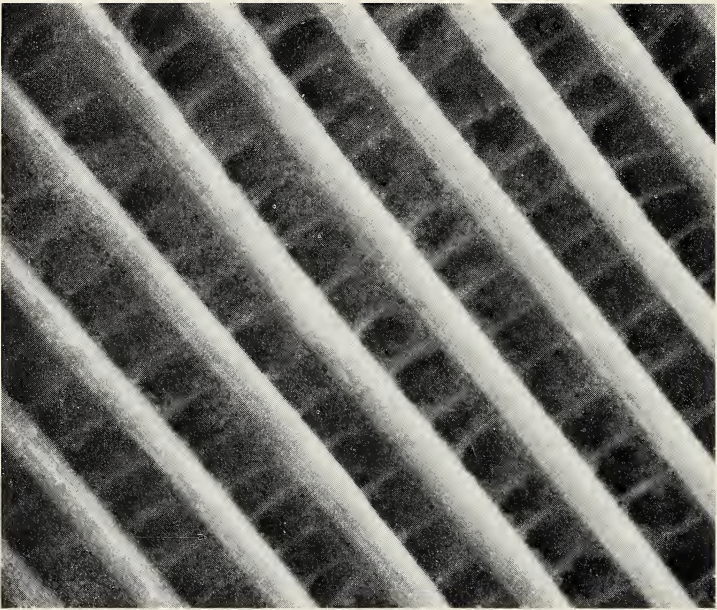
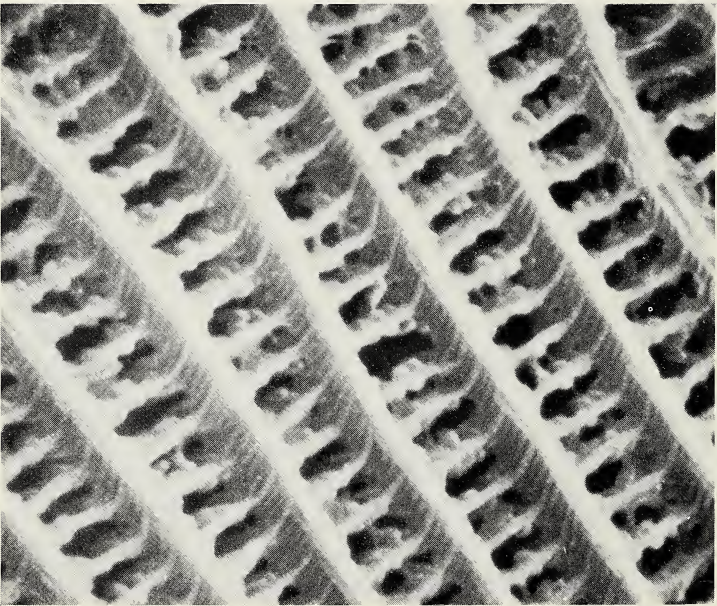


Fig. 2a.—Upper surface, orange scales.

To expose the underside of the scales, the wing was pressed onto a surface coated with contact adhesive (the backing used for Polaroid color prints), and the wing membrane was peeled off to leave the scales perfectly transferred. This method is successful because the peduncles (stems) are loosely held in sockets on the membrane, the scales of the upper and under layers being attached at alternating sockets (Gray, 1961).



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Figs. 2b, c.—Upper surface, orange scales.

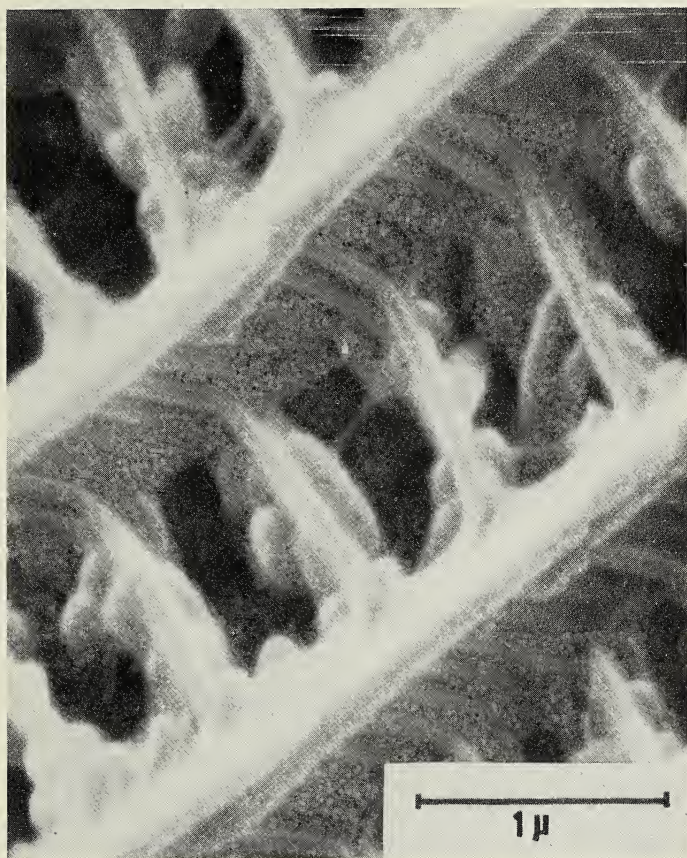


Fig. 2d.—Upper surface, orange scales.

OBSERVATIONS

Results are shown in Figs. 2-7. It is interesting that there are marked differences in fine structure among the four varieties of scales whose upper surfaces were examined and also between the upper and lower surfaces of the same (orange) scale. Butterfly scales long have been described as hollow, as suggested by the holes visible in the photomicrographs. The hollowness of the peduncle seems apparent in Figs. 4b and c. It has been speculated (Portier, 1932) that the scales and peduncles of the genus *Parnassius* are hollow and therefore admit air, communicate with tracheal capillaries in the wing, and play a role in respiration.

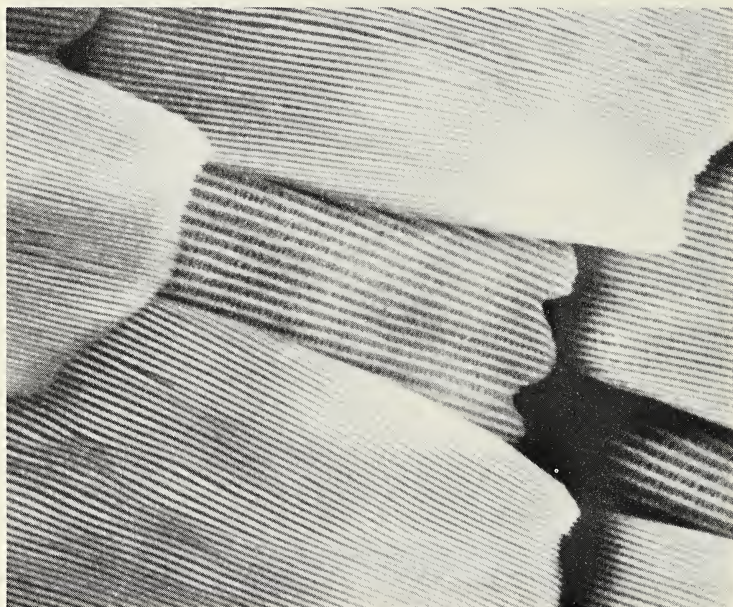
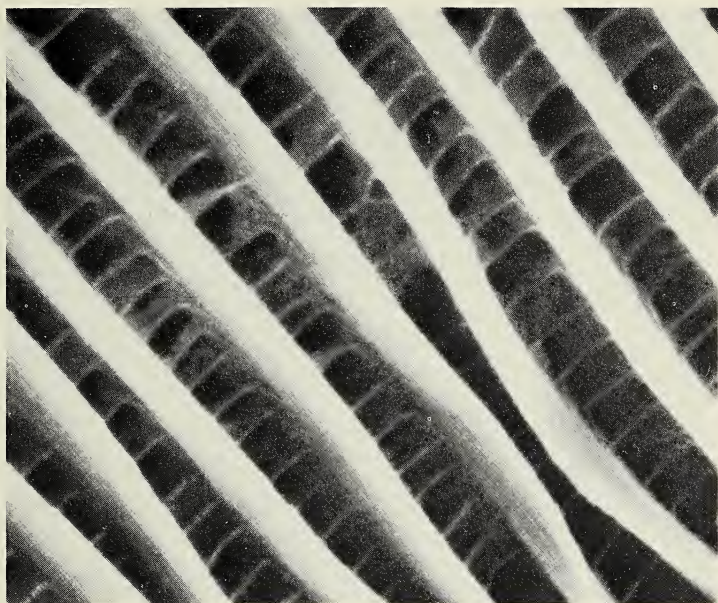
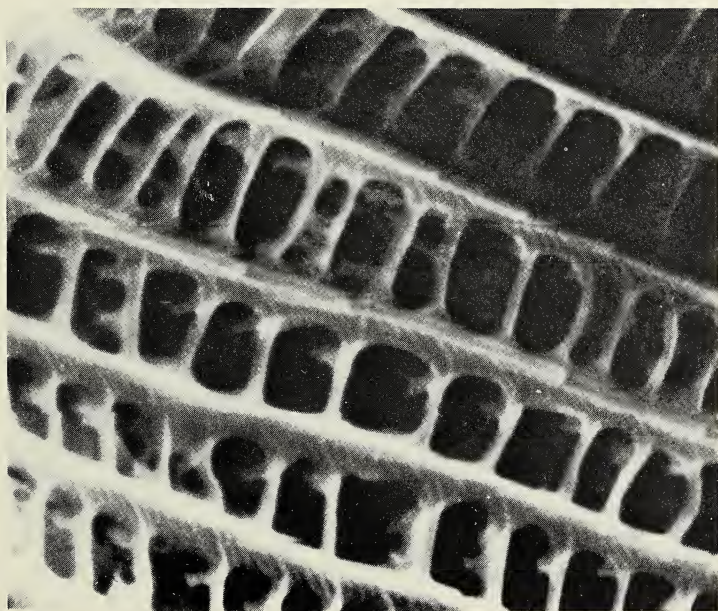


Fig. 3a.—Upper surface, washed orange scales.

The fine structure of the orange scales visible at 10,000X (Figs. 2b and c, 3b and c) resemble a "double grating" or network. The distance between the lengthwise ribs is approximately 1.5 microns, and that between the cross-ribs or connecting ribs ranges from approximately 0.5 to 0.7 micron. The thickness of the cross-ribs is approximately 0.07 micron. In some orange scales the cross-ribs appear to be partially interconnected by a thin skin or membrane (Fig. 2b) whereas in other orange scales most of the cross-ribs are not interconnected but exhibit small ellipsoidal structures that appear to be suspended from them (Figs. 2c and d). The above-described two types of orange scales are found in different positions with respect to the "shingling" arrangement (Fig. 2a) on the wing membrane; the scales with the ellipsoidal particles (Fig. 2c) occupy the lower layer and are partially covered by the upper-layer scales shown in Fig. 2b.



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Figs. 3b, c.—Upper surface, washed orange scales.

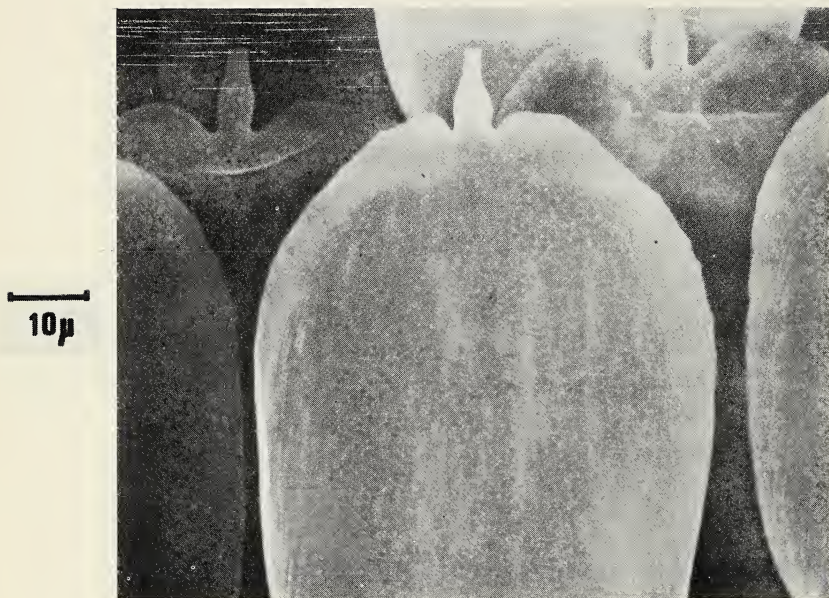
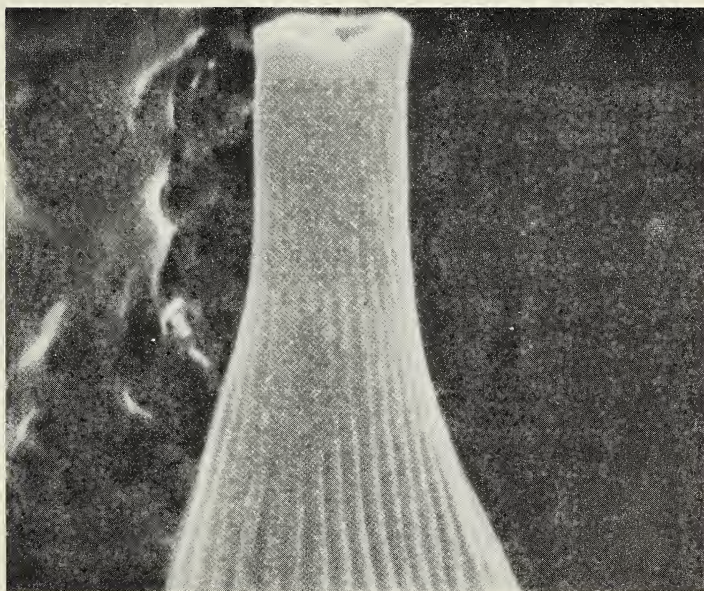
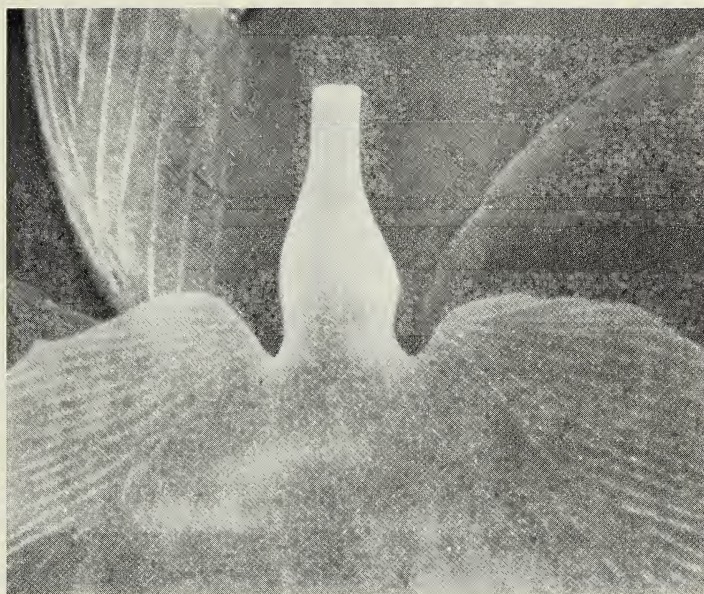


Fig. 4a.—Under surface, orange scales.

The orange color was removed completely by dipping a wing first in 95% ethanol and then for only 20 seconds in 20% aqueous ammonia (the color was transferred to the solution as the pteridines were dissolved as their ammonium salts). Then the wing was dipped in water, then ethanol, and allowed to dry in the air. Photomicrographs of the washed scales are shown in Fig. 3. The treatment seemed to make no change in the upper-layer scales (Fig. 3b vs. Fig. 2b), but in the case of the under-layer scales the suspended particles appear to have been largely removed to give a more open network (Fig. 3c vs. Fig. 2c). Whether and to what extent the ellipsoidal particles are related to the color remains to be established.

The under surface of the orange scale shown in Fig. 4 appears to be without much detailed fine structure. There are no ribs except on the peduncle and the periphery of the scale. This observation suggests that the scale resembles a hollow pouch consisting of two significantly different sheets—a continuous bottom membrane and a cross-ribbed upper sheet which is more or less porous depending on the type of scale and its position on the wing.



Figs. 4b, c.—Under surface, orange scales.

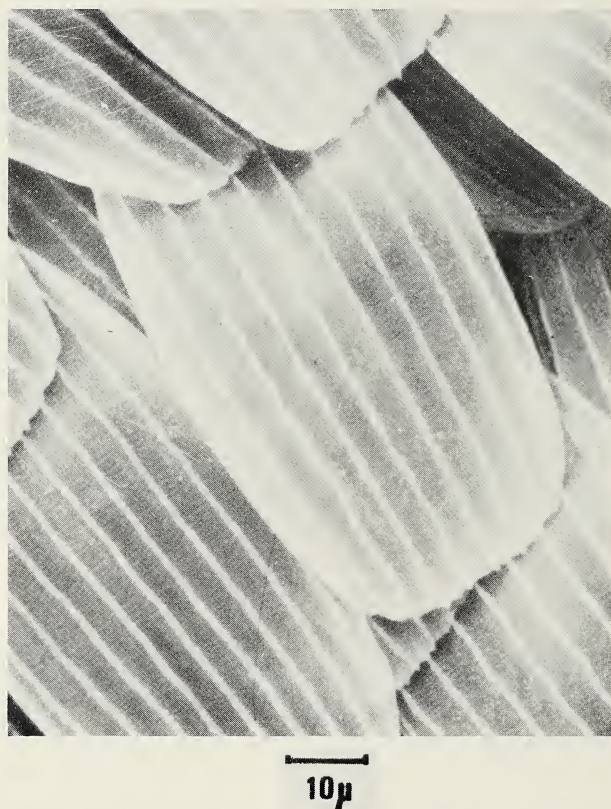
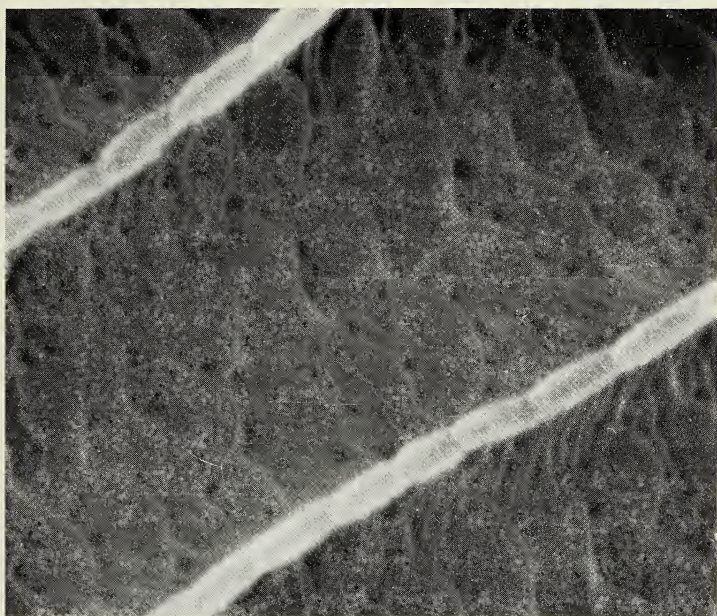


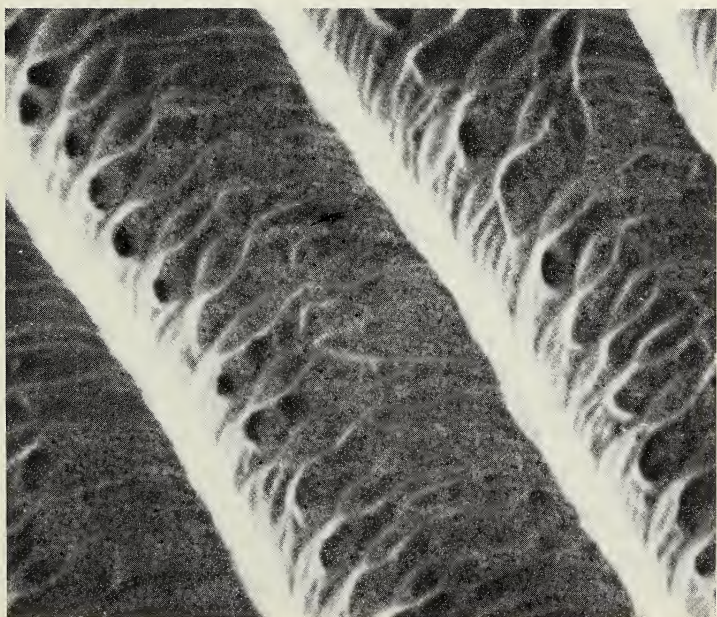
Fig. 5a.—Upper surface, black scales.

The fine structure of the upper surface of the black scales (Fig. 5) is strikingly different from that of the orange scales. The distance between the lengthwise ribs is approximately 3 to 6 microns as compared to 1.5 microns in the orange scales. Also, the trough-like material between the lengthwise ribs of the black scales displays intricate patterns which cannot be described as "cross-ribs" (Figs. 5b and c).

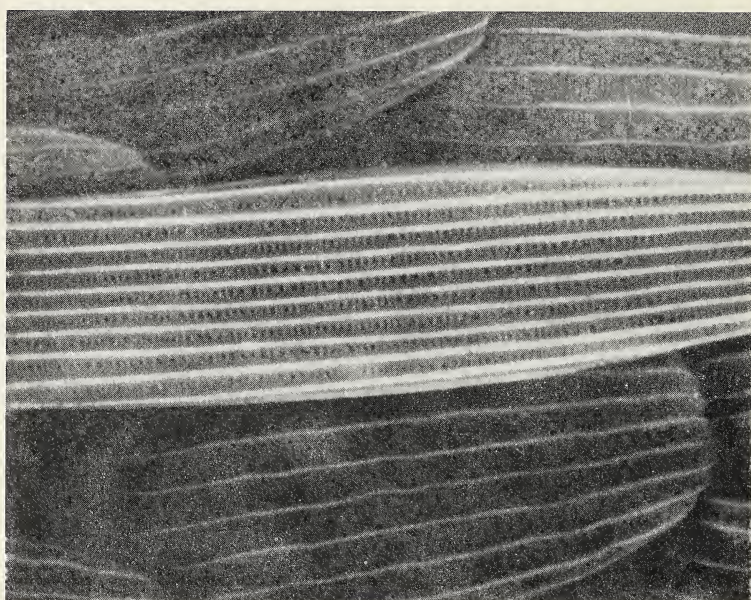
Interspersed among the black scales are brightly-colored yellow scales in which the distance between the lengthwise ribs is approximately 3 to 4 microns. The presence of cross-ribs, and particulate matter in some areas, is indicated (Fig. 6b).



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Figs. 5b, c.—Upper surface, black scales.



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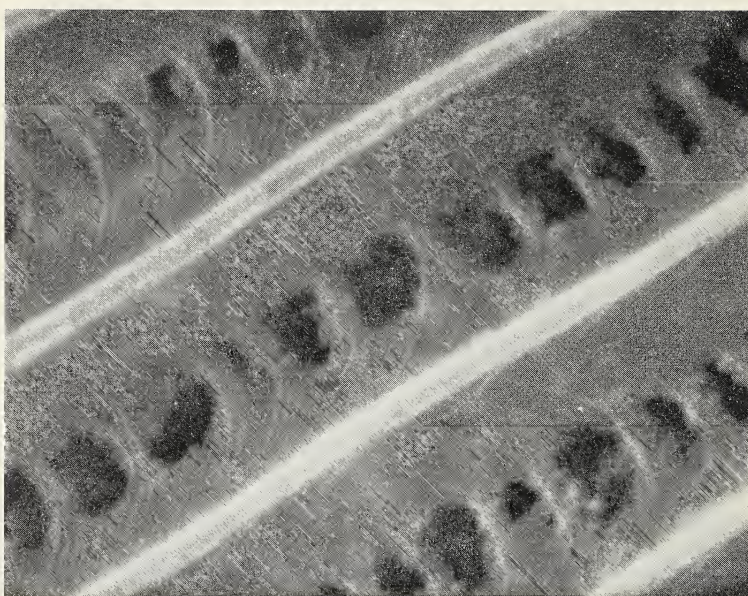


Fig. 6a, b.—Upper surface, yellow scales.

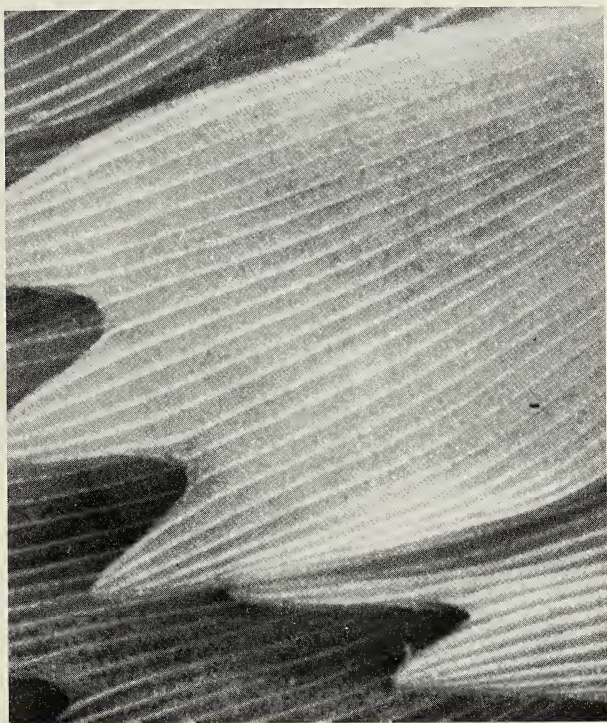
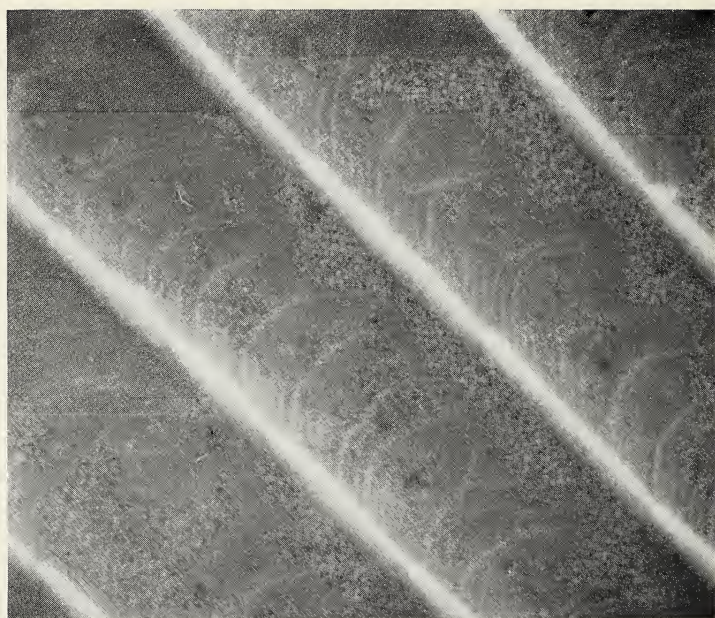
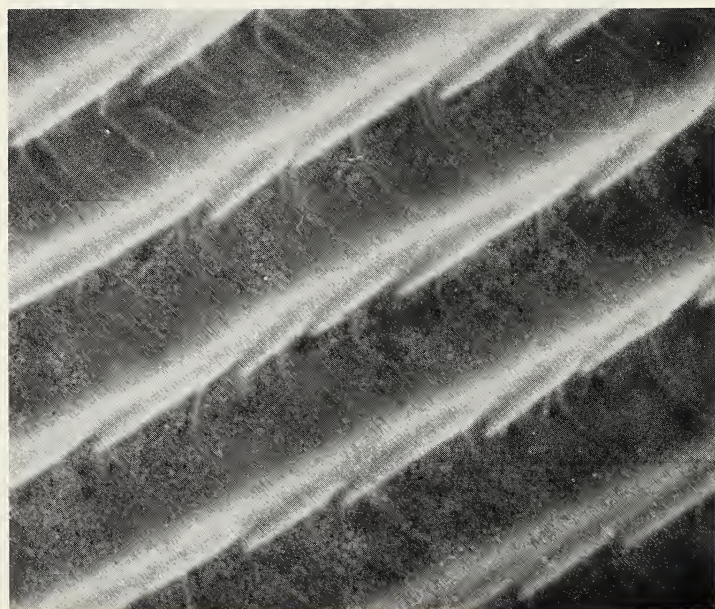


Fig. 7a.—Upper surface, pink fringe scales.

The final type of scales examined, the pink fringe scales, exhibit lengthwise ribs that are approximately 2 to 4 microns apart; the inter-rib distance varies from a minimum of about 2 microns at the basal region to a maximum of about 4 microns toward the tip of the scale. Tilting of the specimen showed clearly that the lengthwise ribs are composed of overlapping short narrow "scales" (Fig. 7c). The material connecting the lengthwise ribs in this case forms a continuous trough and appears to be supported by faintly-visible cross-ribs.



11



Figs. 7b, c.—Upper surface, pink fringe scales.

SUMMARY

Fine structure varied greatly with color and position. The upper surface of an orange scale, cross-ribbed and perforated between the lengthwise ribs (1.5 microns apart), was strikingly different from the smooth and continuous lower surface as well as from the upper surface of a black scale, on which the ribs (5 to 6 microns apart) were connected by intricately-patterned "troughs". The peduncles (stems), as well as the scales themselves, appear hollow.

ACKNOWLEDGMENTS

We thank the Corporate Chemical Research Laboratory of the Allied Chemical Corporation for kindly providing facilities for this work and Mr. Ronald Galante for his assistance in preparing the photomicrographs.

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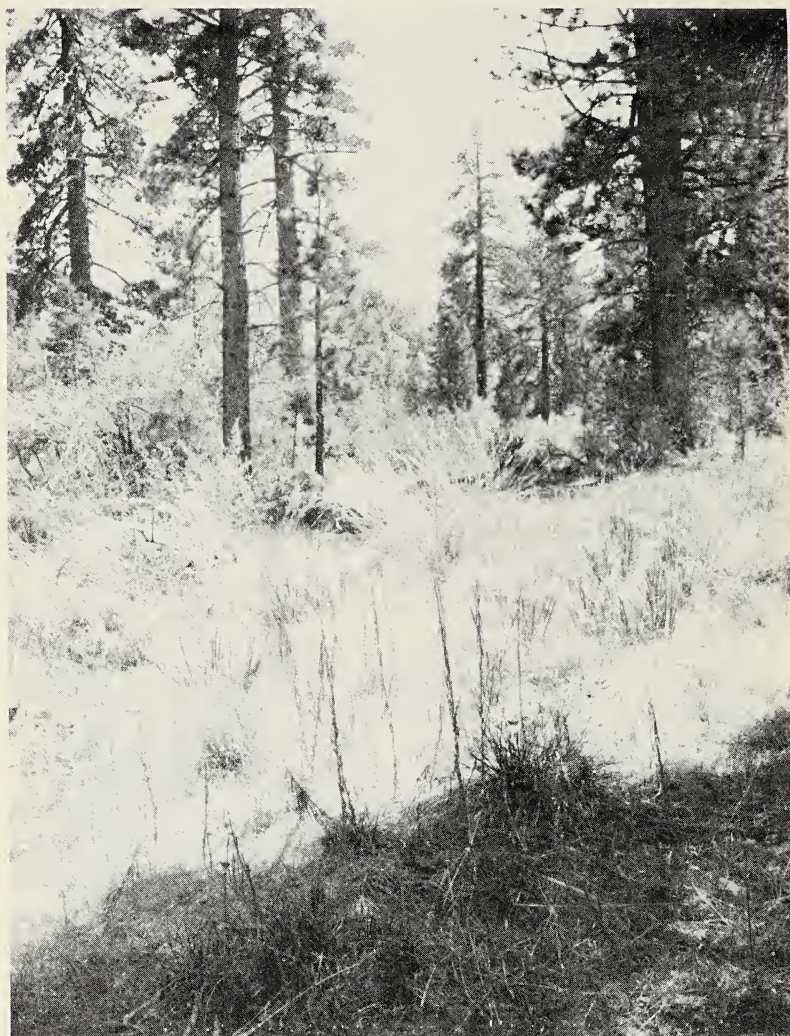


Fig. 1.—Scene on north side of Sugarloaf Mt., *Arabis holboelli* var. *pinctorum* in foreground.

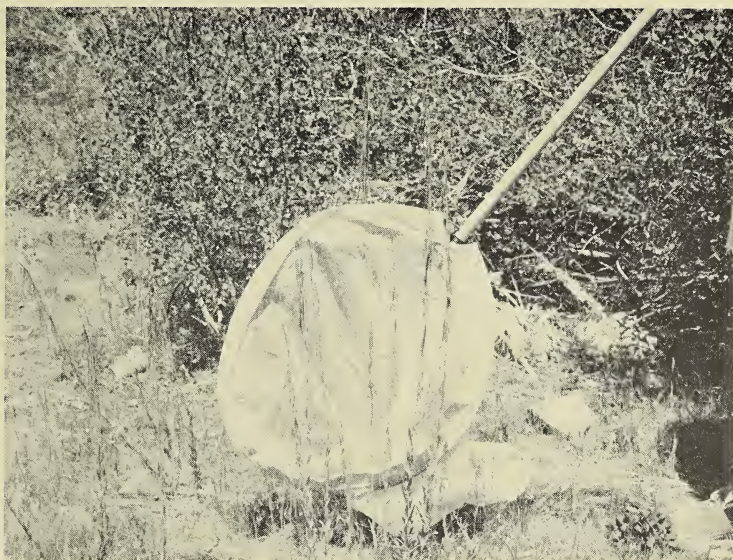


Fig. 2.—Closeup of food plant shown in Fig. 1.

HABITAT — *Euchloe hyantis andrewsi*

Paul A. Opler has recently indicated the distribution of nearctic *Euchloe* (J. Res. Lepid. 7(2):65-86). On his map (Fig. 4 as cited), the populations from the San Bernardino mountains, California, are designated by the name *E. hyantis andrewsi*. Collections of this race in July, 1970 were made by the author at the east end of the San Bernardino mountains on the north side of Sugarloaf Peak at about 8000 feet elevation (Fig. 1 and Fig. 2). Females were noted to be laying eggs on *Arabis holboellii* Hornem. var. *pinetorum* (Tides.) Roll. which was quite abundant in the vicinity. Plant identification was kindly made by Dr. James Hendrickson.

W. Hovanitz

Fig. 2. *Eurema desjardinsi*. 1. Imago; 2. Egg; 3. Larva on hatchings; 4. 7th Segment, 1st instar; 5. Head, 1st instar; 6. Larva, 3rd instar; 7. 7th Segment, 2nd instar; 8. Larva, 4th instar; 9. 7th Segment, 4th instar; 10. Larva, final instar; 11. 7th Segment final instar; 12. Spiracle enlarged; 13. Head, final instar; 14. Pupa; 15. Cremastral hooks much enlarged; 16. 7th Segment, 3rd instar; Food Plant: *Cassia mimosides*.

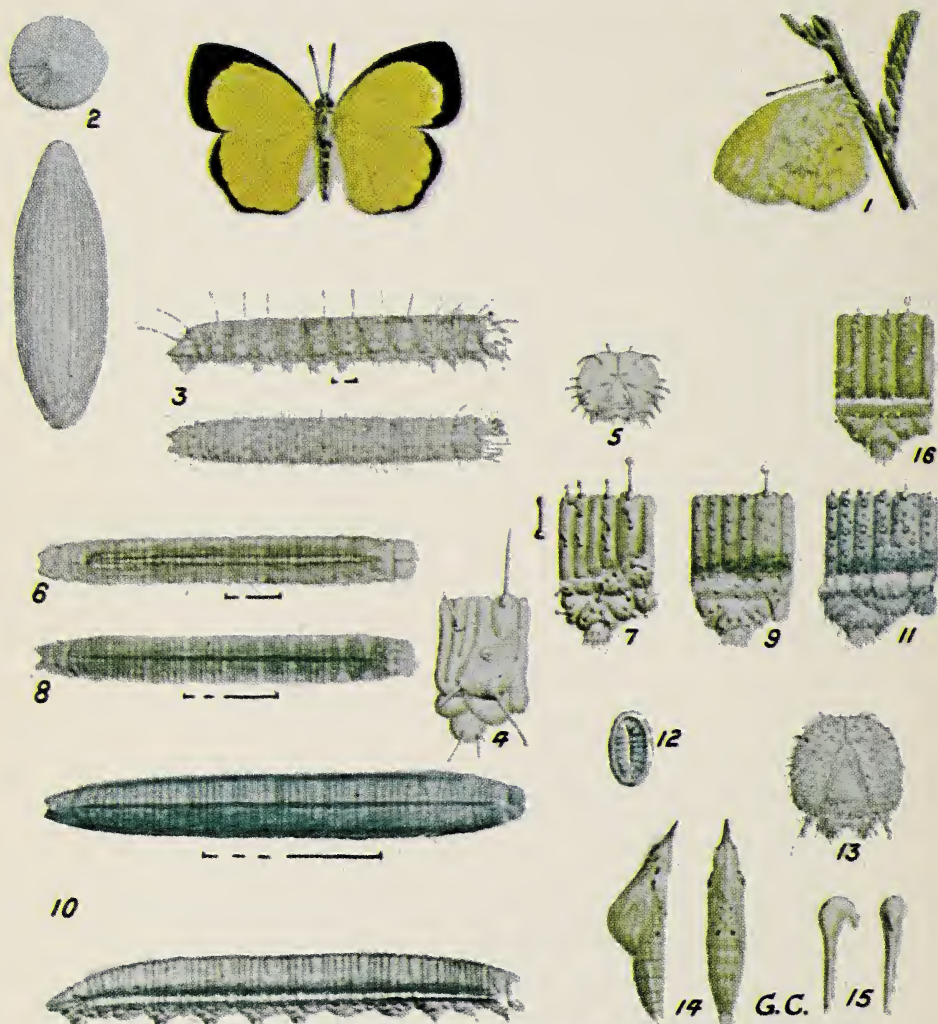
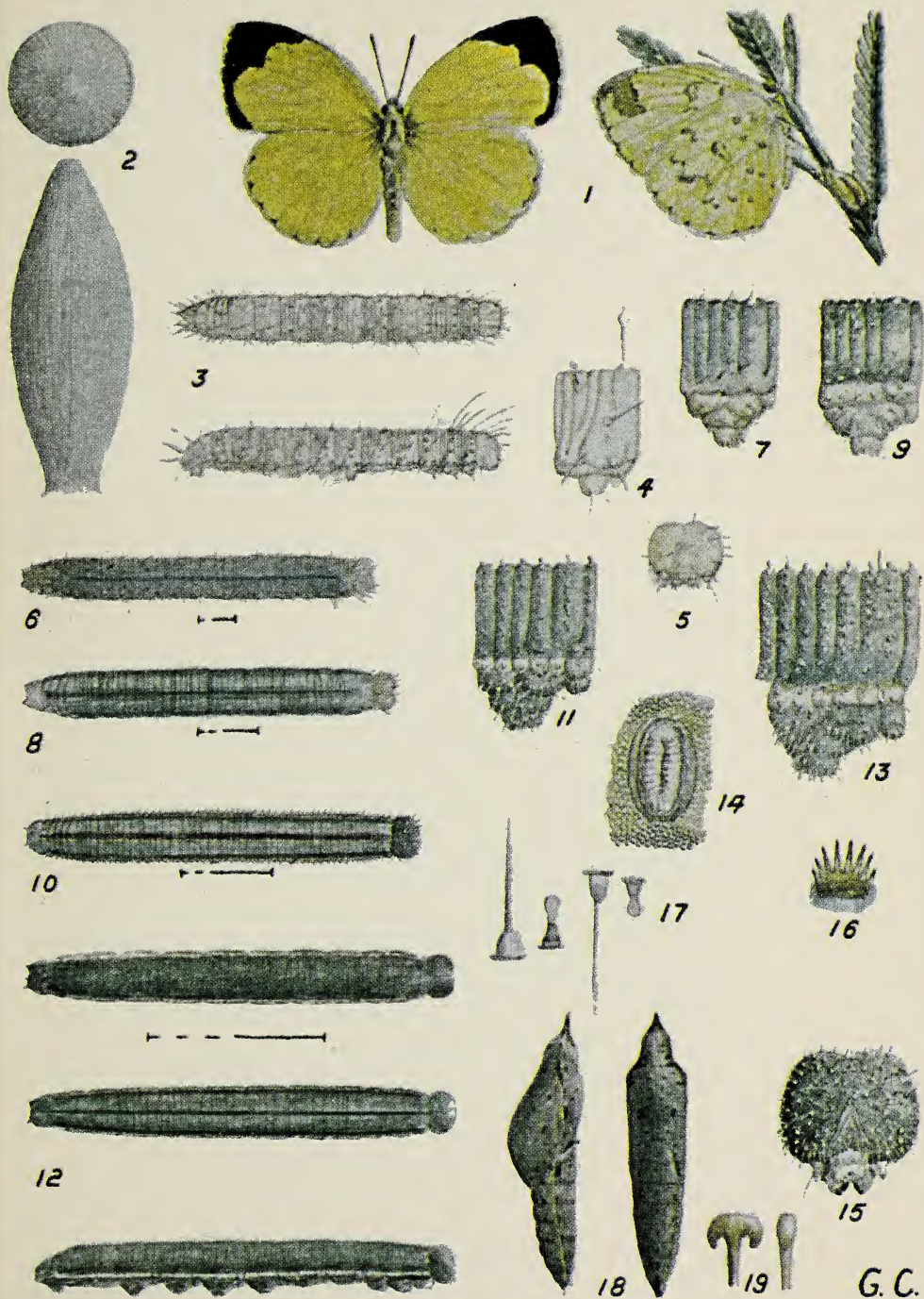


Fig. 1. *Eurema hecabe*. 1. Imago; 2. Egg; 3. Larva, 1st instar; 4. 7th Segment, 1st instar; 5. Head, 1st instar; 6. Larva, 2nd instar; 7. 7th Segment, 2nd instar; 8. Larva, 3rd instar; 9. 7th Segment, 3rd instar; 10. Larva 4th instar; 11. 7th Segment, 4th instar; 12. Larva final instar; 13. 7th Segment, final instar; 14. Spiracle; 15. Head final instar; 16. Anal comb; 17. Setae, much enlarged; 18. Pupa, cremastral hooks much enlarged; Food Plant: *Cassia mimosides*.

Reprint of Fig. 1 and Fig. 2 from
Clark, G. C. and C. G. C. Dickson. 1965.
J. Res. Lepid. 4 (4) :252-257.



HOVANITZ

HABITAT — *ARGYNNIS NOKOMIS*

Argynnis nokomis is found throughout the basin and range country from the eastern side of the Sierra Nevada to the Rocky Mountains in widely separated isolated spots where there are cold water seepages, and acid bogs, in the midst of otherwise alkaline country. As with other *Argynnis* around the world, the food plant is probably *Viola*, though it has not been identified at this locality.

W. Hovanitz

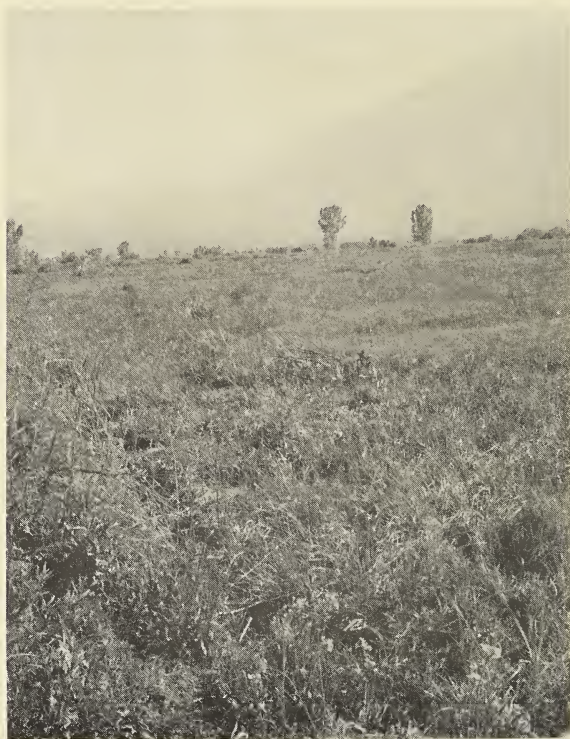


Fig. 1.—Bog in Round Valley, Inyo Co., California, looking south toward the Sierra Nevada. June, 1970. Adults fly primarily in late July and August.

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BUTTERFLY LARVAL FOODPLANT RECORDS AND A PROCEDURE FOR REPORTING FOODPLANTS¹

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INTRODUCTION

IN RECENT YEARS there has been much interest in the relationships between plants and butterflies (e.g., Brower and Brower, 1964; Ehrlich and Raven, 1965). In much of the past work the method of recording this data has been inaccurate and unsystematic. The importance of accurately determined larval foodplants of butterflies has been recognized by some workers but neglected by many others. Progress in this field has been slow; as late as 1947 there were a large number of North American species for which not a single foodplant was known, including certain common species (Remington, 1947b).

Larval foodplants aid in constructing the biology of the butterfly since spatial and temporal distribution, abundance, and sometimes the color pattern of the adult are directly dependent on foodplants. Thus, one of the keys to the biology of the butterfly ultimately depends on the precise identification of its larval foodplant(s). Although some species such as *Vanessa cardui* (Linnaeus) and *Strymon melinus* Hubner utilize a wide variety of plants, most species appear to be restricted to a few or even a single plant species. Butterfly foodplants may even help to determine plant distribution; e.g., *Speyeria* indicate that *Viola* is

¹The term "foodplant" is used throughout this paper since it refers to a plant that the insect habitually feeds on, as opposed to "hostplant" which refers to a plant that the insect lives on (Torre-Bueno, 1937).

present, a plant that is sometimes not noticeable in a locality at certain times of the year.

In view of numerous errors now present in the literature, it is *critical* that a standardized procedure be established to more accurately determine foodplant-butterfly relationships, since no such procedure exists. In this work we propose a procedure for systematically identifying and reporting plant-butterfly records so that they can be referred to accurately and with assurance. We will also discuss past good and bad practices, methods used to find foodplants, and will report foodplant records for 14 butterfly species based on one season of observation. Additional records will be reported in future papers.

REVIEW OF LITERATURE ON FOODPLANTS; VALUE OF FOODPLANTS

Some literature concerning insect-foodplant relationships is available. A series of papers deal with food selection in phytophagous insects (Brues, 1924; Dethier, 1953, 1954, 1968; Fraenkel, 1953; Thorsteinson, 1960; Cartier, 1968; Schoonhoven, 1968). Discussions of the effects of available food in relation to oviposition and larval dispersal (Dethier, 1959a, b), visual and chemical stimuli used during oviposition (Ilse, 1937; Cripps, 1947; Fox, 1966; Schoonhoven, 1968), and the variation in selectivity of foodplants (Forbes, 1958; Straatman, 1962a; Stride and Strattman, 1962) are available for butterflies. Hovanitz and Chang (1962a, b, 1963a, b, c, d, e, 1964) performed a series of laboratory experiments with *Pieris* species, principally *Pieris rapae* L., to determine oviposition preferences and responses, factors affecting foodplant preferences of the larvae, and the effect of the foodplant on the larva's survival and growth rate. Some work has been done with foodplant specificity in sibling species of butterflies (Remington and Pease, 1955; Remington, 1958. Emmel and Emmel (1962) discuss factors that limit butterfly species to particular foodplants and thus influence the amount of plant utilization. Downey (1962) found that foodplant association in *Plebejus icarioides* (Boisduval) may depend on other factors besides the particular lupine species, such as pilosity and hybridization in the plant, ant symbiosis, parasites, competitors, and soil types.

Three major sources to locate butterfly foodplants for North America are Edwards (1889), Davenport and Dethier (1937), and Dethier (1946). These cite the literature but do not critically evaluate the foodplants given. J. A. Comstock has published a series of life history studies of North American butterflies that

includes foodplants, in *the Bulletin of the Southern California Academy of Sciences*. Kendall (1959, 1964, 1965, 1966) recorded foodplants for certain Texas butterflies, and Remington (1952) reported foodplants for some Colorado species. Detailed work has been done with the foodplants of one species, *Plebejus icarioides* (Downey and Fuller, 1961; Downey, 1962). Work on foodplants of butterflies in other countries (e.g., Scudder, 1874; Platt, 1921; Stokoe, 1944; Allan, 1949; Iwase, 1954, 1964; Dickson, 1965) may assist in finding new foodplants for North American species.

Although our knowledge of butterfly foodplants is at a far less complete state than butterfly taxonomy, foodplants have already proved to be a valuable tool in interpreting certain evolutionary trends. Effects of competition and predation on foodplant selection in butterflies are discussed by Brower (1958a, b). By analysis of foodplants of three closely related species of *Papilio*, Brower (1958b) suggests that competition among the larvae probably produced restricted and mutually exclusive diets. (However, D. V. McCorkle, personal communication, found larvae of two of these, namely *Papilio eurymedon* Lucas and *P. multicaudata* Kirby, feeding on the same *Prunus* species in Washington.) Brower (1958a) also found evidence that food preferences of butterflies that are procryptic and palatable to birds result from selective pressure favoring those on mutually exclusive plants due to birds concentrating on a common prey image. Brower and Brower (1964) found a strong correlation between adult butterflies being unpalatable to vertebrate predators and a narrow range of larval foodplants containing poisonous substances. Dethier (1941) examined various species of citrus and parsley families and found that these plants have certain essential oils in common that probably account for their attractiveness to *Papilio* larvae. Similarly, Ehrlich and Raven (1965, 1967) concluded from a systematic evaluation of plants eaten by certain butterfly subgroups that butterflies may feed on plants distantly related phylogenetically but which contain similar secondary plant substances. From this they suggest that butterflies and plants are co-evolving. Breedlove and Ehrlich (1968) found that the seed set of *Lupinus amplus* Greene was strikingly reduced by larval infestation of *Glaucopsyche lygdamus* (Doubleday) in one lupine population in Colorado, indicating that this butterfly could be a strong selective agent on this plant species. Hovanitz (1949: 351, 353) points out that man can accelerate the rate of hybridization between two *Colias*

species by disturbing the habitat and enabling weeds to encroach. *Colias christina* Edwards thus entered the dwarf willow habitat of *C. gigantea* Strecker in southern Canada and *C. philodice* Godart entered the *Vaccinium* habitat of *C. interior* Scudder in northern Michigan following their foodplant invasion along roadsides.

One practical aspect of knowing the foodplants for butterflies is in plotting the butterfly's distribution. For example, *Speyeria nokomis* (Edwards), a species usually found in isolated colonies, can be discovered in new localities by locating herbarium records for *Viola nephrophylla* Greene within its known range and elevation limits.

ERRORS

Past work dealing with butterfly foodplants has often been imprecise, inadequate, and erroneous. Burns (1964:18), in ascertaining *Erynnis* foodplants, said "rampant misidentification is a serious source of error, hard to detect," and lightly dismissed many old records. Downey (1962) said that "considerable error" exists for butterfly foodplants in the literature. He attributes this to (1) data based on single observations and (2) casual identification of the suspected plants. Ehrlich and Raven (1965), in summarizing foodplant relationships in butterflies, say that "extreme care has been taken in associating insects with particular food plants, as the literature is replete with errors and unverified records." They mention that despite erratic oviposition behavior often displayed by butterflies, oviposition records are frequently considered as foodplant records. Brower (1958b) pointed out sources of error from evaluating foodplants of three western United States *Papilio* species: (1) authors often failed to indicate whether or not they reared adults from larvae for positive identification, (2) worn females of the three species look alike in flight so that oviposition records without capturing the females are subject to error, and (3) later authors often quote earlier authors who were mistaken in their information.

Examples of the kinds of errors that are made may help focus attention on the pitiful state of our knowledge of butterfly foodplants and may suggest ways to remedy the situation. Tietz (1952) states that "every effort has been made to list all foodplants where they are known," but usually gives no references to the foodplants listed. He noted *Battus philenor* (Linnaeus) ovipositing on *Polygonum scandens* L. and thus listed it as a foodplant. Also, among *Euphydryas phaeton*'s (Drury) food

plants were listed *Ribes*, *Corylus*, and *Fraxinus*, all unlikely to serve as foodplants. Garth and Tilden (1963) did not designate foodplant species because it "would have prolonged the list unduly" and list genera for the most part. Edwards (1868-1872) reported *Polygonia zephyrus* (Edwards) on *Azalea occidentalis* (now known as *Rhododendron occidentale* (T. & G.) Gray) and later (1884) corrected his mistake in two places, saying that the larva and pupa that were drawn referred to *Polygonia faunus rusticus* (Edwards). Despite this correction many texts since have continued to list *Azalea* as a *zephyrus* foodplant. One of the present authors (JFE) reported (1962) that *Lycaena cupreus* (Edwards) larvae were found on *Calyptridium umbellatum* (Torr.) Greene; they were not reared to adult. Despite the fact that a female *cupreus* was seen to oviposit on the *Calyptridium* earlier in the season, it is probably not the foodplant; a later investigation of the area in 1965 by JFE revealed that a *Rumex* species, probably the true foodplant, was growing abundantly among the *Calyptridium*. The larvae that were found are now thought to have been *Strymon melinus*, but this is only speculation. This example emphasizes the need to follow through on observations of oviposition before considering a plant as a food source. One wonders how certain peculiar errors ever developed in the first place, such as *Neophasia terlooti* Behr feeding on "mistletoe" (Forbes, 1958). Stokow (1944) and Allan (1949) did not distinguish between laboratory and field rearings for species of foodplants of British butterflies.

Species are often said to feed on a common plant, implying that a particular species is a general feeder on that group of plants. For example, references to *Polygonia satyrus* (Edwards) on "nettle", *Satyrrium sylvinus* (Boisduval) on "willows", and many satyrines and hesperiids on "grasses" are common. The inaccuracy of such statements is pointed out by the fact that not one specific grass genus, let alone species, is known for a North American satyrine. (However, N. McFarland, *in litt.*, reports a *Cercyonis* larva on *Dactylis glomerata* L. 5 miles W. of Corvallis, Oregon.) A sedge may be the foodplant of the satyrine *Euptychia mitchellii* (French) (McAlpine, Hubbell, and Pliske, 1960) and sedges are strongly suspected for at least one species of *Oeneis* (JFE and OS, personal observation).

Brower (1958b) traced one error down. Comstock had reported the foodplant for *Papilio rutulus* Lucas as "hop", which was reported elsewhere as *Humulus* when he meant *Ptelea Baldwinii* T. & G. (Hop-Tree). In *Philotes*, the *Eriogonum* food-

plant is quite specific for any given population, yet Downey in Ehrlich and Ehrlich (1961) states that they feed on "*Eriogonum*".

One problem with erroneous foodplant determinations is that it is difficult to *unprove* them or even sometimes to distinguish them from legitimate records when no documentation accompanies the statement. Sometimes apparently legitimate records by reputable workers are erroneous, such as W. H. Edwards reporting *Papilio indra* Reakirt as feeding on *Artemisia dracunculus* L. (Emmel and Emmel, 1963). It will be a long, slow process to weed out erroneous records, and it would be advisable to duplicate legitimate records with adult and plant reference material. Records suspected to be erroneous should be corrected when new data dictates it. For example, Davenport and Dethier (1937) gave *Lotus glaber* Greene and *Astragalus* sp. as well as *Purshia glandulosa* Curran reported in the literature as foodplants for *Callipsyche behrii* (Edwards). The reference to *Purshia* is well documented (Comstock, 1927, 1928). The range of the adult corresponds to that of *Purshia* and the larvae have subsequently been found on *Purshia* but the other two records have never been duplicated. A look at the original source (Williams, 1908) reveals that the *Lotus* and *Astragalus* records refer to "*Lycaena behrii*", plainly a species of "blue" from the context.

At a somewhat lower level, subspecies of plants are not often given, although such a reference can be important. For example, *Papilio indra fordi* Comstock & Martin was originally described as feeding on *Cymopterus panamintensis* Coult. & Rose, although it does *not* occur on the nomotypical subspecies but rather only on the subspecies *acutifolius* (Coult. & Rose) Munz (JFE, unpublished). Sometimes certain records are common knowledge yet are not published; this is also a type of error.

Some authors are of the opinion that choice of foodplants is an indication of butterfly relationships (Ae, 1958; Forbes, 1958; Garth and Tilden, 1963:16). Garth and Tilden (1963) cite as an example certain *Colias* species that feed on *Vaccinium* instead of "preferred" legumes and therefore should be set apart from others of their genus. However, there is some evidence that this is a conditional argument. For example, considering morphological characters, *Papilio indra* and its subspecies, strictly Umbelliferae feeders, are not closely related to the *P. machaon* L. species complex which has species that feed on Umbelliferae, Compositae (*Artemisia dracunculus* for *P. bairdii* Edwards), and Rutaceae (*Thamnosma montana* Torr. & Frem. for *P. rudkini* Com-

stock). Using foodplants here for taxonomic purposes, that would make *P. indra* closer to the *P. machaon* complex than either *P. bairdii* or *P. rudkini* is. The potential of foodplant relations as data for butterfly classification is discussed by Downey (1962).

REPORTING PROCEDURE AND COLLECTING METHODS

To help overcome the mistakes made in the past in reporting foodplants, we wish to establish certain guide-lines to follow. Several such attempts have been made in the past. Remington (1947a) proposed that the Lepidopterists' Society would have a botanist available to determine foodplants; however, the idea apparently did not materialize. Opler (1967), in giving new foodplants for *Anthocaris sara* Lucas and *A. lanceolata* Lucas, confirmed the determinations with a botanist, gave exact locality and date that the plant was collected, gave the circumstances under which the plant was found to be a food source, and even reported the determination down to "varieties" (=subspecies). However, no place of deposition was assigned for the plants or immatures. Remington (1952) deposited foodplants at a designated herbarium.

Foodplants should be determined by a competent botanist and placed on file with a recognized herbarium specifically referred to for later inspection if ever needed. (Herbaria of the world are listed in Lanjouw and Stafleu, 1959, with their proper abbreviations). Some groups of plants must be determined by a specialist. Herbarium records are always mandatory. Certain groups such as *Agave* and *Lupinus* as yet have not been revised satisfactorily. We hope that eventually all North American butterflies will have their foodplants on file in herbaria for future reference.

A plant press should be part of the standard equipment of the lepidopterist concerned with butterfly biology. Flowers and/or fruit are essential for determination of most plant species. In instances where oviposition or immatures occur on plants with no flowers or fruit, leaf characteristics should be carefully compared with surrounding plants (to be used for specimens), and this should be stated when recording the plant. When a female oviposits on a plant species that is not in bloom, it is sometimes necessary to return to the exact spot later in the season or the following year to collect the same plant with flowers or fruit (the plant should be marked). Also, plants that ovipositing females are "interested in" may also be the clue to finding the

foodplant; suspected foodplants, properly documented, are valuable to report since they assist in finding new foodplants.

Just as preserving foodplants is a necessity, preservation of the butterfly stage connected with the foodplant is extremely important. Whether it was an ovipositing female or adults ultimately reared from in situ larvae, or eggs, larvae, or pupae compared with known species, the material should be preserved and deposited in a designated museum for later reference by future workers. This is particularly important in case of future revisions and the naming of new subspecies.

Giving the locality of the foodplant is important because different foodplants are often used in different localities, and the same species that serves as a foodplant in one locality may not serve as a foodplant in another locality (Downey, 1962). Vegetation type is important to report. For example, we found *Satyrium fuliginosum* (Edwards) only in sagebrush areas even though its foodplant, a *Lupinus* species, occurred in other habitats. The condition of the foodplant is often important. Frequently species will prefer to oviposit on seedlings of the foodplant or on plants without flowers. *Vanessa virginiensis* (Drury) oviposits on *Gnaphalium* seedlings (Dethier, 1959a) and *Vanessa cardui* will oviposit on small, second growth thistles (Keji, 1951).

Evidence of feeding may be important in determining new localities for a species when no immatures or adults are present. For example, Megathyminae larvae construct "trap doors" and "tents", and *Papilio bairdii* larvae strip *Artemisia dracunculus* stems of leaves and deposit a characteristic type of feces on the ground.

Surprisingly little has been written about methods of locating foodplants of butterflies. Kuzuya (1959) told how to locate theclini eggs in winter in Japan, which helps to locate their foodplants. McFarland (1964) discussed methods of collecting Macrolepidoptera larvae. In the future, it would be helpful to know the location of eggs on the foodplant and what part of the plant the larvae eat, to assist in finding immatures and foodplants. For example, we found *Lycaena* eggs in stem axils and *Euphydryas* egg masses only on the underside of the leaves. Larvae may feed on certain parts exclusively such as young leaves, flowers, or bark. Also, the manner in which the eggs are laid is important (singly, clusters, or small groups).

The behavior of females is often a clue in discovering foodplants. A female repeatedly alighting on the same plant species

and curling her abdomen toward the plant should be watched. If the female does not lay eggs on the plant, the plant should be checked anyway for eggs from other females. Certain females such as *Speyeria*, *Parnassius*, and *Satyrrium fuliginosum* do not always oviposit directly on the foodplant, so that choice of food with these is the responsibility of the young larva. *Hesperia lindseyi* Holland oviposits on lichens or some other substrate; the larvae must select the proper grass species (MacNeill, 1964:32). Female oviposition on a plant may not necessarily mean the plant is a foodplant. Examples of "mistakes" by females are well known. Coolidge (1925) found *Hylephila phylaeus* (Drury) ovipositing on grasses, rocks, twigs, and even a paved street. *Speyeria* oviposit on dried leaves (Ritchie, 1944), various plants (Guppy, 1953), and *Artemisia* bark (Durden, 1965), but the larvae eat leaves of *Viola* species. There are examples of butterfly species ovipositing on introduced plants on which the resultant larvae do not survive (Remington, 1952; Brower, 1958b; Brooks, 1962; Straatman, 1962b; Sevastopulo, 1964).

In the genera *Euphydryas*, *Chlosyne*, and *Phyciodes*, it is sometimes easier to search for larval webs on suspected foodplants in summer or fall after the adults have flown than it is to follow females or to search for eggs. Newcomer (1967) found larvae of *Chlosyne hoffmanni manchada* Bauer on *Aster conspicuus* Lindley by looking for larval webs in July after the adults had flown.

Knowing only one species' foodplant can be useful in locating foodplants for other members of the same genus (e.g., *Speyeria* and *Euphydryas*). Sometimes it may be helpful to locate areas where few possible foodplants are available so that the foodplant can be located easily. For example, *Ochlodes yuma* (Edwards) flies in some areas where its foodplant, *Phragmites communis* Trin., is the only grass present.

In problem groups such as Satyrinae, it may be necessary to place possible foodplants with caged females for clues or to statistically analyze the numbers of young larvae that crawl toward, feed on, and remain on a variety of plant species placed in a petri dish.

Often the areas where females oviposit are away from the flight areas of the males; locating such areas of female concentration increases the probability of finding foodplants. For example, we found an area where *Colias scudderii* Reakirt females

were ovipositing on low-growing *Salix* plants in only one small section of a willow bog in Colorado.

Knowing when is the best time to find foodplants can be useful. Langston (1963) states that the appearance of *Eriogonum*-feeding *Philotes* adults is correlated with the early full-bloom of *Eriogonum*. Thus a knowledge of the blooming time in this case helps to locate immatures and their foodplants.

Using a technique suggested by Mr. Christopher Henne (personal communication), we have had success in finding lycaenid larvae in flowerheads by drying out picked flowers of the suspected plant, thus forcing the larvae to crawl up the sides of the container in search of fresh food.

DEPOSITIONS AND DETERMINATIONS

Foodplant records have been recorded intermittently by two of us (JFE and OS) since 1967. The number by the plant is the collector's number (for J. F. Emmel) for the plant. The deposited butterfly material is labelled to include this number. The herbarium sheets with the exception of the Umbelliferae will be deposited with their respective species at the Dudley Herbarium, Stanford University, Stanford, California (DS); the Umbelliferae will be deposited at the U. C. Berkeley Herbarium, Berkeley, California (UC); and the preserved butterfly material will be deposited at the Los Angeles County Museum, Los Angeles, California.

Most of the plants were identified by one of us (DEB). Species of the genus *Eriogonum* were identified by Dr. James L. Reveal, Department of Botany, University of Maryland, College Park, Maryland, and the Umbelliferae were determined by Dr. Lincoln Constance, Department of Botany, University of California, Berkeley, California.

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FOODPLANT RECORDS

(All collected by JFE and OS unless otherwise noted. Plant genera of the world can be placed to family by reference to Willis, 1966.)

PIERIDAE

1. *Colias alexandra* Edwards. Wasatch Plateau, 10,000', near Mt. Sanpete, E. of Ephraim, Sanpete Co., Utah, 31 July 1967,

- female oviposited at 11:30 AM MST on leaf of *Astragalus miser* Dougl. ex Hook. (Leguminosae), *J. F. Emmel* 25 (DS).
2. *Colias meadii* Edwards. Cottonwood Pass, 12,200', Chaffee Co., Colo., 28 July 1967, female oviposited between 8:20-9:30 AM MST on leaf underside of *Trifolium dasyphyllum* Torr. & Gray (Leguminosae), *J. F. Emmel* 22 (DS).
 3. *Euchloe ausonides coloradensis* (H. Edwards). (A) Dry meadow at 9600', Gothic, Gunnison Co., Colo., 10 July 1967, female oviposited at 10:00 AM MST on flower bud of *Arabis drummondi* Gray (Cruciferae), *J. F. Emmel* 6 (DS). (B) North side of Schofield Pass, 10,400', Gunnison Co., Colo., 14 July 1967, female oviposited at 2:00 PM MST on flower bud of *Descurainia californica* (Gray) O. E. Schulz (Cruciferae), *J. F. Emmel* 11 (DS). (C) Schofield Pass, 10,500', Gunnison Co., Colo., 18 July 1967, female oviposited at 1:30 PM MST on flower bud of *Descurainia californica* (Gray) O. E. Schulz (Cruciferae), *J. F. Emmel* 13 (DS).
 4. *Pieris napi* (Linnaeus). (A) East River at 9600', in wet meadow among willows, near Gothic, Gunnison Co., Colo., 10 July 1967, female oviposited at 10:00 AM MST on leaf underside of *Cardamine cordifolia* A. Gray (Cruciferae), *J. F. Emmel* 7 (DS). (B) Meadow $\frac{1}{2}$ mile S. Brush Creek Cow Camp, 9000' near the East River, Gunnison Co., Colo., 12 July 1967, female oviposited at 10:00 AM MST on leaf underside of *Thlaspi arvense* L. (Cruciferae), *J. F. Emmel* 10 (DS). (C) Cement Creek, Gunnison Co., Colo., 18 July 1967, female oviposited at 2:00 PM MST on leaf underside of *Thlaspi arvense* L. (Cruciferae), *J. F. Emmel* 14 (DS).
 5. *Pieris occidentalis* Reakirt. (A) East slope of Belleview Mountain, 11,700', near Schofield Pass, Gunnison Co., Colo., 25 July 1967, female oviposited at 11:30 AM MST on leaf underside of *Thlaspi alpestre* L. (Cruciferae), *J. F. Emmel* 21 (DS). (B) Rockslide above Island Lake, 10,500', Ruby Mts., Elko Co., Nev., 8 Aug. 1967 (collectors JFE, OS, and S. Ellis), female oviposited at 10:15 AM PST on leaf underside of *Draba cuneifolia* Nutt. ex T. & G. (Cruciferae), *J. F. Emmel* 32 (DS).

NYMPHALIDAE

1. *Chlosyne acastus* Edwards. In washes along road, 9 miles W. of Vernal on U.S. Hwy. 40, Uintah Co., Utah, 21 Aug. 1967 (collectors JFE, OS, and S. Ellis), two larvae on plant stems, pair reared to adult (emerged 22 Feb. 1968, male; 21 Feb. 1968, female), on *Machaeranthera viscosa* (Nutt.) Greene

- (Compositae), J. F. Emmel 39 (DS).
2. *Chlosyne palla calydon* Strecker. On grassy slope with aspen, sagebrush, and *Castilleja*, near Brush Creek Cow Camp above the East River, 9100', Gunnison Co., Colo., 27 Aug. 1967, larva in web near base of stems (adult formed inside pupa, a male; genitalia identical to *C. palla* from Colorado in the Los Angeles County Museum and to the drawing in Ehrlich and Ehrlich, 1961), on *Erigeron speciosus* (Lindl.) DC (Compositae), J. F. Emmel 41 (DS).
 3. *Polygonia zephyrus* (Edwards) Charleston Park, 8300', Charleston Mts., Clark Co., Nev., 31 Aug. 1967, larva on stem (male emerged 16 Sept. 1967) of *Ribes cereum* Dougl. (Saxifragaceae), J. F. Emmel 45 (DS).
 4. *Speyeria atlantis dodgei* (Gunder). Lost Prairie, W. of Santiam Pass on U.S. Hwy. 20, Linn Co., Ore., 12 Aug. 1967 (collectors JFE, OS, and S. Ellis), female oviposited on leaf underside (female reared from this female, emerged 6 Apr. 1968) of *Viola bellidifolia* Greene (Violaceae), J. F. Emmel 36 (DS).

LYCAENIDAE

1. *Glaucopsyche lygdamus oro* Scudder. Large, open, dry meadow, north side of Schofield Pass, 10,400', Gunnison Co., Colo., 14 July 1967, female oviposited at 1:45 PM MST on flower bud of *Lupinus ammophilus* Greene (Leguminosae), J. F. Emmel 12 (DS).
2. *Plebejus argyrognomen ricei* (Cross). (A) Lost Prairie, W. of Santiam Pass, on U.S. Hwy. 20, Linn Co., Ore., 12 Aug. 1967 (collectors JFE, OS, and S. Ellis), female oviposited at 12:15 PM PST on stem near base of plant of *Vicia exigua* Nutt. (Leguminosae), J. F. Emmel 38 (DS). (B) Lost Prairie, W. of Santiam Pass, on U.S. Hwy. 20, Linn Co., Ore., 12 Aug. 1967 (collectors JFE, OS and S. Ellis), female oviposited at 12:30 PM PST on stem near base of plant of *Lathyrus torreyi* Gray (Leguminosae), J. F. Emmel 37 (DS).
3. *Plebejus saepiolus* (Boisduval). (A) Crested Butte Cemetery, 8900', Crested Butte, Gunnison Co., Colo., 12 July 1967, female oviposited inside flower-head between flowers of *Trifolium repens* L. (Leguminosae), J. F. Emmel 8 (DS). (B) Crested Butte Cemetery, 8900', Crested Butte, Gunnison Co., Colo., 12 July 1967, female oviposited inside flower-head between flowers of *Trifolium longipes* Nutt. (Leguminosae), J. F. Emmel 9 (DS). (C) Trail from Pine Creek Camp to Mt. Jefferson, 10,500', Toquima Range, Nye Co., Nev., 4 Aug.

1967 (collectors JFE and S. Ellis), female oviposited at 1:00 PM PST on side of flower of *Trifolium monanthum* Gray (Leguminosae), J. F. Emmel 29 (DS).

HESPERIIDAE

1. *Hesperia uncas* Edwards. Hilltop 2 miles S. of Gunnison, 8000', Gunnison Co., Colo., 27 Aug. 1967, female oviposited at 11:10 AM MST on leaf underside of *Bouteloua gracilis* (HBK.) Lag. (Gramineae), J. F. Emmel 42 (DS).
2. *Thorybes mexicana nevada* Scudder. Open dry meadow near Crested Butte Cemetery, 8900', Crested Butte, Gunnison Co., Colo., 30 June 1967, female oviposited at 10:55 AM MST on leaf underside of *Lathyrus leucanthus* Rydb. (Leguminosae), J. F. Emmel 2 (DS).

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NOTICES

BOOKS:

BUTTERFLIES. A concise guide in colour. Josef Moucha, ill. by Vlastimil Choc. Paul Hamlyn, Hamlyn House, The Centre, Feltham, Middlesex. G.B.

BIOGEOGRAPHY OF THE SOUTHERN END OF THE WORLD. Philip J. Darlington, Jr. McGraw Hill paper back reprint, N.Y.

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NOMENCLATURE OF WING VEINS AND CELLS

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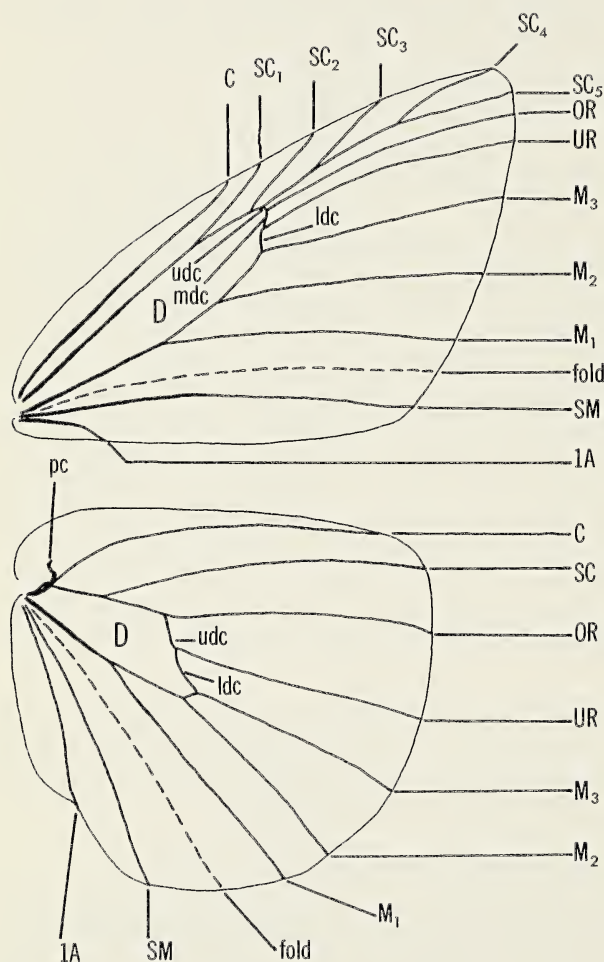
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IDEALLY THE NAMING OF VEINS and the cells between them should be uniform and in at least general agreement; unfortunately, in surveying the literature one soon finds that such is not the case. There are many systems for naming veins and almost as many for cell nomenclature. Each author obviously uses that system most familiar to him, usually disregarding other schemes, and thus adds to the confusion of the reader. This bewilderment is most apparent when a non-lepidopterist attempts to use some of the systems that are purely oriented to Lepidoptera and that bear little or no relationship to the schemes employed for other orders of insects. I therefore present this paper in an attempt to unravel some of the confusion generated by the differences in these diverse systems, but I will also engage in some "evangelism" in behalf of that scheme that I feel is most advantageous.

The references below to the different workers employing the various systems only deal with those works on the New World butterflies — the reconciliation of the schemes used in papers on moths will have to be done by another author.

THE HERRICH-SCHÄFFER SYSTEM

One of the earliest systems for naming veins, and certainly the oldest one that has survived into the relatively modern literature, was devised by Herrich-Schäffer over a century ago and first used in his writings. As shown in Fig. 1, in this system the most anterior forewing vein is the costa (C), the next five are branches of the subcosta (from the anterior one, SC₁, SC₂, SC₃, SC₄ and SC₅), the following two are the *ober*-radius (OR) and *unter*-radius (UR), the next three are branches of the medius (M₃,



No designation for extradiscal cells in the system

Fig. 1.—Venation of a hypothetical butterfly according to the Herrich-Schäffer system. The abbreviations are explained in the text.

M_2 and M_1 , from anterior to posterior; the rationale here being that M_1 arises nearer the base than does M_2 , etc.), and the most posterior vein that is present in all butterflies is the sub-medius (SM). If the small vestigial vein posteriad of SM is present, as it is in the Papilionidae, it is known as the first anal vein (1A). The hindwing venation is as follows: the short, spur-like vein near the base and antieriad of the first main vein is the precosta (pc), the anterior main vein is the costa (C), the second the subcosta (SC), the next two the *ober*-radius (OR) and *unter*-radius (UR), the following three the branches of the medius (respectively, M_3 , M_2 and M_1), the next one (the most anterior one not connected to the discal cell) the sub-medius (SM) and the most posteriad vein is the first anal (1A). On both wings the anterior vein delimiting the discal cell is the subcosta and the posterior vein the medius. The forewing crossveins between SC_5 and OR, OR and UR, UR and M_3 are the first (upper), second (middle) and third (lower) discocellulars (respectively, udc, mdc and ldc). The hindwing crossveins between SC and OR, OR and UR are the first or upper (udc) and second or lower (ldc) discocellulars, respectively.

There are no provisions for naming cells in this system, except for the discal cell (D) which is the same in all schemes.

Although the Herrich-Schäffer system is not in current usage, it is of interest to American workers since it is employed in those sections of Seitz' *Macrolepidoptera of the World* contributed by Fruhstorfer, Haensch, Röber and in some of Weymer's discussions. This system is also the one used by Godman and Salvin in the *Biologia Centrali-Americana*, and the venation drawings of Ithomiidae in Holland's *Butterfly Book* were taken from another author using the Herrich-Schäffer system.

THE "INDIAN" SYSTEM

The "Indian" system, used chiefly by de Nicéville and Moore in their various writings on the butterflies of the Indian region, affects Americans only peripherally in comparisons of the Old and New World faunas. This system differs very little from that of Herrich-Schäffer: OR and UR of the forewing are designated, respectively, Discoidal 1 and Discoidal 2; hindwing vein SC of Herrich-Schäffer is the first subcostal (SC_1) in the present system, OR is the second subcostal (SC_2), UR is the Discoidal and 1A is the Internal nervule.

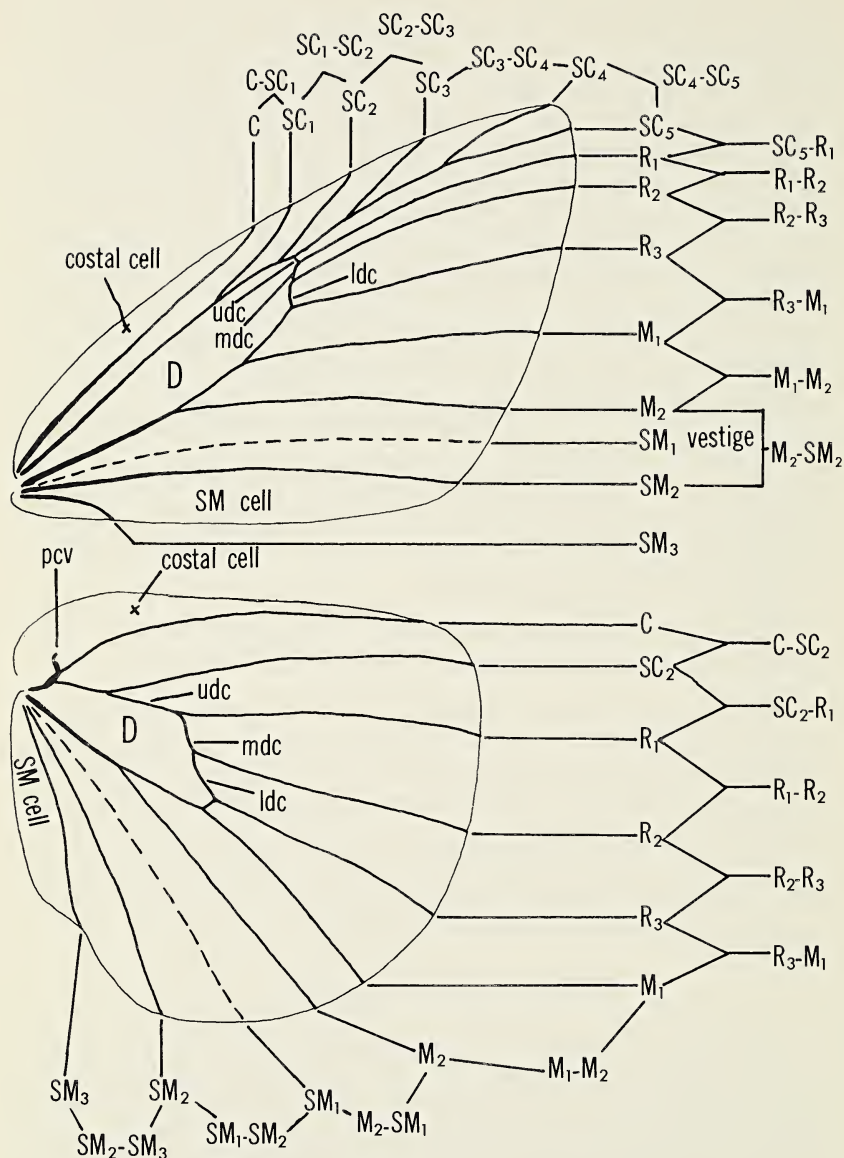


Fig. 2.—Venation and extradiscal cells of a hypothetical butterfly according to the Rothschild-Jordan system. The single symbols represent the names of veins, and the double ones (*i. e.*, M₁-M₂) represent cells, as explained in the text.

THE ROTHSCHILD-JORDAN SYSTEM

The Rothschild-Jordan system (Fig. 2), based in part on the Herrich-Schäffer system, was the most comprehensive one proposed to its time. In this scheme the most anterior forewing vein is again the costa (C), the next five branches of the subcosta (SC₁, SC₂, SC₃, SC₄ and SC₅, from anterior to posterior), the next three are branches of the radius (R₁, R₂ and R₃, from the most anteriad), the following two branches of the medius (M₁ the anterior and M₂ the posterior), and those veins arising posteriad of the cell are the submedians (SM); the most anterior of these (SM₁) is considered absent and represented by only a fold, the one present in all Lepidoptera is SM₂ and the tiny, posterior spur is SM₃. The forewing crossveins between SC₅ and R₁, R₁ and R₂, R₂ and R₃ are, respectively, the upper (udc), middle (mdc) and lower (ldc) discocellulars. On the hindwing the short basal spur anterior to the main veins is the precostal vein (pcv), the anterior main vein is the costa (C), the second the second subcosta (SC₂, SC₁ being considered absent), the next three are branches of the radius (from the anterior one, R₁, R₂ and R₃), the following two are branches of the medius (M₁ anteriad and M₂ posteriad) and those veins arising posteriad of the discal cell are the submedians (SM): the anterior SM₁ is only a fold in most butterflies, whereas the middle SM₂ and the posterior SM₃ are always present. The upper (udc), middle (mdc) and lower (ldc) discocellulars delimit and end of the discal cell between veins SC₂ and R₁, R₁ and R₂ and R₂ and R₃, respectively

The naming of the spaces between the veins outside the discal cell (D) was formalized in the Rothschild-Jordan system with great precision. The cells are named for the veins bounding them, so that the space between veins M₁ and M₂ is denoted M₁-M₂, for example. The cells anteriad of C and posteriad of the last SM are, respectively, the costal cell and the SM cell.

The Rothschild-Jordan system was used widely by authors in the last decade of the last century and the first thirty years of this one. In works pertaining to the American butterflies Holland adopted the system in *The Butterfly Book* (with the exception of the venation drawings of ithomiids mentioned in the discussion of the Herrich-Schäffer system), and the Rothschild-Jordan scheme is employed in those parts of Seitz authored

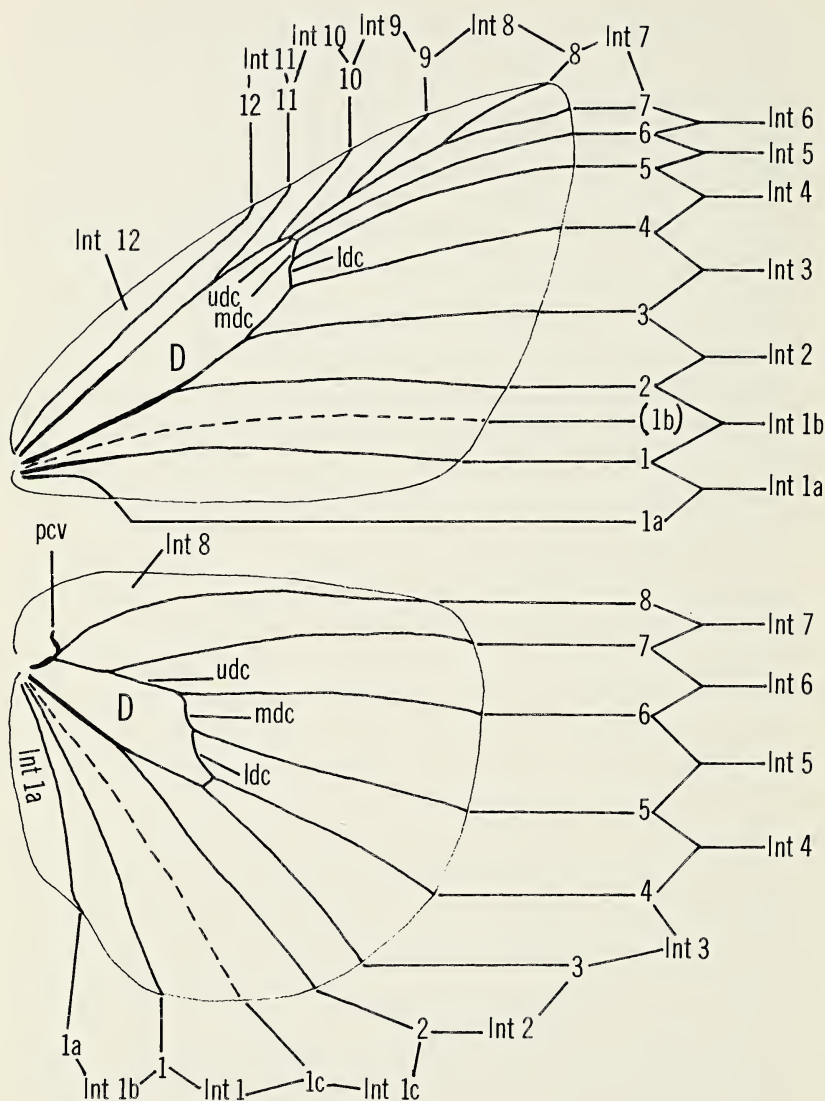


Fig. 3.—Venation and extradiscal cells of a hypothetical butterfly according to the "English", or numerical, system. Those symbols preceded by "Int" refer to the cells, and the numbers alone refer to the veins, as explained in the text.

by Seitz, Jordan and Draudt. Naturally, the system is employed in Rothschild and Jordan's revision of the American *Papilio*.

THE "ENGLISH", OR NUMERICAL, SYSTEM

The "English", or numerical, system (Fig. 3) is a totally artificial system whose major advantage is its great simplicity. In this scheme the main veins of both wings are named from the most posterior to the most anterior: hence, all butterflies have veins 1-12 on the forewing and veins 1-8 on the hindwing. The only source of confusion concerning the nomenclature of veins is in the designations of those which arise posterior to the discal cells (D) of both wings. On the forewing the vestigial vein posteriad of vein 1 is denoted as 1a (the fold between veins 1 and 2 represents the primitive vein 1b), and on the hindwing the possible veins posteriad of the cell are veins 1c, 1 and 1a, from the cell to the inner margin. The hindwing precostal vein (pvc) of other systems bears no special designation in the "English" system and the discocellular veins (udc, mdc and ldc) of both wings are as in the Rothschild-Jordan system.

The naming of the extradiscal spaces (Int.) is equally simple: the cells are named for the veins *posteriad* of them — thus the cell between veins 6 and 7 is known as Int. 6. The only apparent inconsistency concerns the spaces on either side of vein 1 of both wings. The cell antieriad of forewing vein 1 is Int. 1b, and the one posterior to vein 1 is Int. 1a. The hindwing cells from vein 2 and the inner margin are Int. 1c, Int 1 and b respectively.

The numerical system is followed by most British and some American writers. It is chiefly of interest to workers on American butterflies because of its use by Weymer in Seitz (but *not* in his discussions where he uses the Herrich-Schäffer system) and by Evans in his catalogues of the American Hesperidae.

THE COMSTOCK-NEEDHAM SYSTEM

The Comstock-Needham system (Fig. 4) is followed by most present-day American writers, although there are modifications of it utilized by one or another. This scheme is based on the venation of all insects, not just Lepidoptera, and thus has more universal application than other systems. The most anterior forewing vein is denoted the subcosta (Sc), the true costal vein being lost in at least the butterflies, the next five are branches

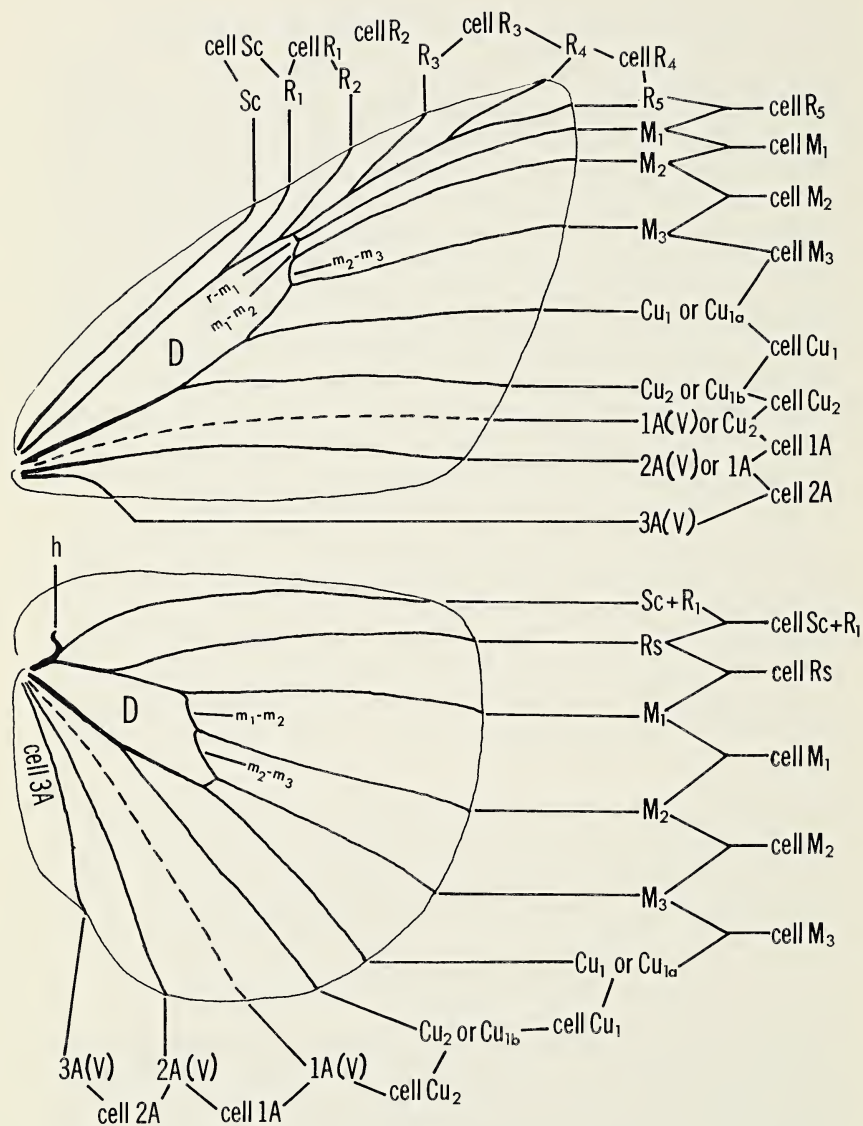


Fig. 4.—Venation and extradiscal cells of a hypothetical butterfly according to the Comstock-Needham system. The symbols are explained in the text.

of the radius (R_1 , R_2 , R_3 , R_4 and R_5 , from the anterior to the posterior one), the next three are branches of the medius (from the anterior, M_1 , M_2 and M_3), the following two are branches of the cubitus (from the anterior, Cu_1 and Cu_2 , or according to some authors, Cu_1 and Cu_1 , respectively), and those veins arising posteriad of the discal cell are the anal veins (A): the one present in all butterflies is known as 2A (it also may be denoted 1A, depending on whether the fold posteriad of the last cubital vein is considered the remnant of 1A or of Cu_2 , and this depending on the interpretation of the cubital veins). The anal veins are also known as vannal veins, in which case they are abbreviated 1V, 2V, etc. The spur vein anteriad of the hindwing main veins (the precostal vein of other systems) is the humeral vein (h), the anterior main vein may be considered as the subcostal vein and the first radial branch ($Sc+R_1$), the second main vein is the radial sector (the fusion of all of the radials except R_1 and abbreviated as R_s , not R_5 as stated by some authors), then come the three branches of the medius (from the anterior to the posterior, M_1 , M_2 and M_3), and the last two veins arising from the cell are branches of the cubitus (again Cu_1 or Cu_1 the anterior one and Cu_2 or Cu_1 the posterior one). The anal (or vannal) veins arise posteriad of the cell and are denoted as 1A (1V), usually absent in butterflies, 2A (2V) and 3A (3V) from the discal cell to the inner margin. The stalk veins delimiting the discal cells of both wings are anteriorly the radius (R) and posteriorly the cubitus (Cu). Many authors still refer to the crossveins at the end of the discal cells as the upper (udc), middle (mdc) and lower (ldc) discocellulars, but the system is explicit in that these crossveins are named for the veins they connect, so that the crossvein between M_1 and M_2 is denoted m_1-m_2 . Note that the initials are in lower case in this instance.

There are at least two methods of designating the extra-discal cells in the current literature: the discal cell (D) is the same in both. Both Klots and the Ehrlich in their books on North American butterflies name these cells for the veins forming their *anterior* boundaries (Fig. 4), so that the cell bounded by veins M_1 and M_2 is cell M_1 . Other authors use a system of naming these spaces similar to that proposed by Rothschild and Jordan (Fig. 5), using the names of both boundary veins to designate a cell; thus, the cell between veins M_1 and M_2 is space M_1-M_2 (note that in this instance the symbols are capitalized to avoid confusion with the terminology for crossveins).

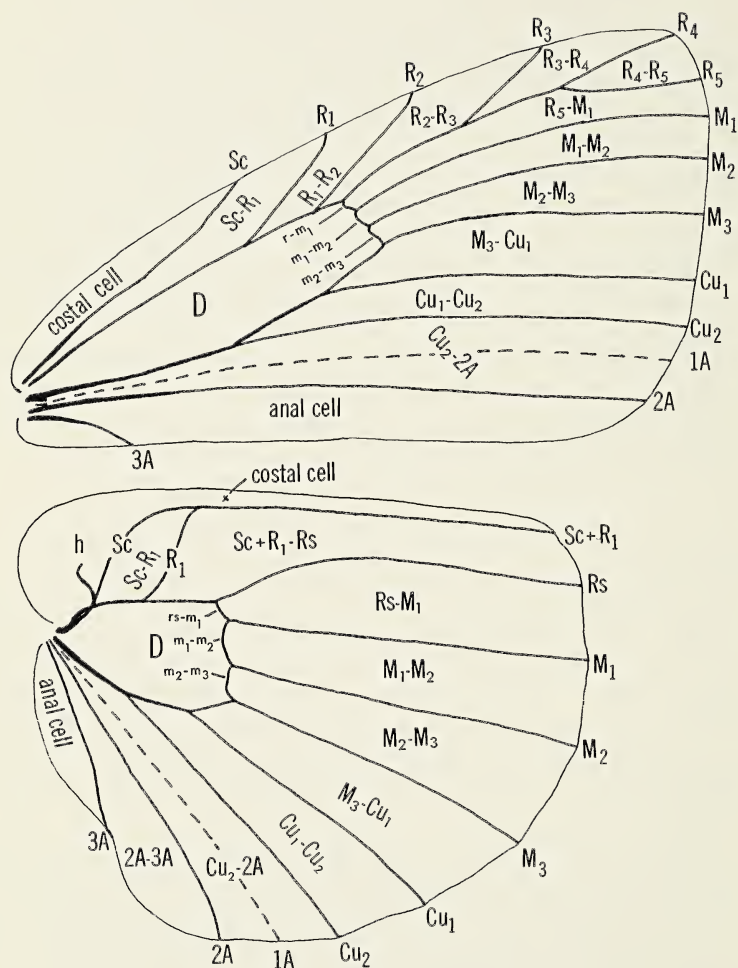


Fig. 5.—Wings of a hypothetical butterfly showing the proposed uniform system of nomenclature for veins and extradiscal cells. The symbols are explained in the text.

SPECIAL STRUCTURES

In the discussion of the various systems I have mentioned the small spur vein at the anterior basal part of the hindwing, the precostal vein (pc, pcv) of older systems or the humeral vein (h) of the Comstock-Needham system. Zeuner (1943, *Ann. Mag. Nat. Hist.*, 11/10: 290) considered that this vestigial vein represented either the costa (C) or the first branch of the primitive subcosta (Sc_1), but other authors have not been certain or have considered that this vein is unrelated to the main veins and arose *de novo* in Lepidoptera.

In a few groups of butterflies, for example, the Brassolinae the proximal part of the anterior main vein of the hindwing is divided into two members (Fig. 5). There is no provision in any of the systems to name these two veins, except the Comstock-Needham system where the anterior member is Sc and the posterior R_1 . The more or less triangular cell formed by these two veins and the anterior boundary of the discal cell is called the precostal, prediscoidal or simply the basal cell in most systems, but may be designated as cell Sc- R_1 in that persuasion of the Comstock-Needham system advocating the naming of the cells for the veins bounding them.

DISCUSSION

The Herrich-Schäffer, "Indian" and Rothschild-Jordan systems simply are not applicable in view of modern evidence as to the identity of veins. Since these systems were based on Lepidoptera only, they are not applicable for other insect groups. The synthetic "English" system is not only inapplicable to other groups of insects but also is not completely reliable for Lepidoptera. This system was devised primarily for butterflies and is singularly fitted only for them, but the scheme may fail when applied to some moth groups that have more or fewer veins. This system is in wide use in the moths, largely because it was employed by pioneer Heterocera workers such as Meyrick and Hampson, but at least the latter author had problems in applying the system uniformly throughout his work. A system, then, to be most valuable must offer the opportunity to draw homologies between the venation patterns of diffuse groups.

The remaining system, the Comstock-Needham system, is the only relatively natural one that can be used not only for Lepidoptera but also for other groups of insects, and, as such, is the

most useful to entomologists. I will not address myself to the problems of cubital and anal vein nomenclature; these are matters for individual workers to decide (which scheme is being employed soon becomes evident from reading a paper, anyway). The use of the Comstock-Needham system enables anyone, lepidopterist or not, to know just what vein is being referred to in a paper on Lepidoptera. Since lepidopterists are also entomologists, and since the Comstock-Needham system is *the* system that is recognized by entomologists of all specialties, it would be best if lepidopterists adopted that system used by the great majority of other entomologists.

The nomenclature of the extradiscal cells is somewhat more difficult. The scheme promoted by Klots and the Ehrlich of naming these cells for the veins *anteriad* of them is in direct opposition to the "English" system in which the cells are named for the veins *posteriad*, and a person familiar with one system will almost invariably misinterpret the other. A non-lepidopterist will incorrectly interpret such notations half the time, if indeed, he can decipher the numerical system at all. By contrast, naming the cells for the veins bounding them removes any confusion as to just what cell is under discussion. This rationale is not new, having originated with Rothschild and Jordan before the turn of the century, but this idea has been more or less ignored recently. However, because of its absolute clarity it seems the best solution to the problem of accurately denoting cells.

An example of this preferred system for naming veins and cells is given in Fig. 5.

ACKNOWLEDGMENTS

I would like to thank my wife, Jacqueline, A. C. Allyn and Dr. E. D. Cashatt for reading this manuscript and making certain suggestions on it, many of which have been incorporated into the final draft.

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NOTES ON
LARVA AND HABITAT OF
CALLOPHRYS FOTIS BAYENSIS
(LYCAENIDAE)

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GUPPY (1959) STATES that *Callophrys fotis mossii* (H. Edw.) has been feeding long enough on its host to evolve a "complicated system of protective coloration." This is also true with *Callophrys fotis bayensis* (Brown). The eggs hatch in three to five days (in captivity) after being laid on the under side of leaves on the flower stock of *Sedum spathulifolium* (Hooker). The larva are green when they hatch; they remain this color, if they continue to feed on green leaves, but if they feed on older red leaves the caterpillars are red or pink. In the last instars, if they feed on the flowers which are yellow, the caterpillars then turn yellow. The pupa is brown with dark specks and a light pubescent covering.

The young and middle instars feed by boring into the thick succulent leaves and by eating the insides; many times the only thing one sees is a pile of wet frass.

In captivity the larvae which feed entirely on flowers are healthier and mature faster than larvae which feed entirely on leaves.

With the staggering rate at which natural areas are being destroyed, it is good to have pictures published of this endangered habitat. A fairly thorough description of the San Bruno Mountains, San Mateo Co., is given by McClintock, and Knight (1968), "A Flora of the San Bruno Mountains, San Mateo County, California." The habitat is an area without trees and

with low growing vegetation, the tallest being approximately three feet. This area gets no protection from wind and fog from the Pacific Ocean.



Fig. 1.—Western Side of the San Bruno Mountains, San Mateo County.

Fig. 2.—North facing slope of canyon below radio towers.

Fig. 3.—*Sedum spathulifolium* (Hooker), small, low growing, flowers approximately six inches tall.

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A POSSIBLE NEW HYBRID COPPER

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Fig. 1.

Dorsal (upper) and ventral (lower) views of male *Lycaena rubidus* (left), *editha* (right), and the hybrid form *rubidus* X *editha* (center). Photography by Don Eames, Portland State College.

AN INTERESTING CURIOSITY appeared this season near Burns, Oregon that should be of interest to students of *Lycaena*. It is an apparent hybrid *Lycaena rubidus* X *editha*. To my knowledge this hybrid has apparently been unreported in nature to date. It is to be retained in the collection of the author.

The specimen was taken in company of normal forms of both *L. rubidus* and *editha* at Devine Canyon, 6 VIII 65, Highway 395, twelve air miles NNE of Burns, Harney County, Oregon at 4,800 feet. The canyon is a primarily pine-juniper area that is surrounded by sagebrush, and associated with a wet meadow along Theimmer Creek that is lined with willow, birch, and aspen. From this locality are also known to occur *L. heteronea*, *cuprus*, and *helioides*.

As can be seen in the photographs, the main distinctions of the hybrid are based on four points; the intermediate nature of the dorsal ground color, the ventral HW pattern, the outline of the FW, and invasion on the DHW anal margin of spots typical of the *editha* pattern. Comparison specimens of *L. editha* and *rubidus* have been pictured also.

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CONTROLLED ENVIRONMENT EXPERIMENTS
WITH PRECIS OCTAVIA CRAM.
(NYMPHALIDAE)

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Continued from:
Journal of Research on the Lepidoptera,
volume 7(1):18.

COLOR PLATE
Larvae and pupa
(adults to come in future issue)



Precis octavia sesamus

"plain" larva, 24°C
 "striped" larva, 24°C

"plain" larva, 30°C
 gold pupa

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ON THE GUNDER COLLECTION OF ARGYNNIDS

(Lepidoptera: Nymphalidae)

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IN CONTEMPORARY BUTTERFLY LITERATURE, F. Martin Brown's numerous papers on earlier collectors and collections have been especially valuable. It is well that students should be reminded of the importance of historical background and especially good that they should learn of the extent to which nomenclature is based on the art of "second guessing". Indeed, it may be uncomfortably close to the truth to say that the majority of taxa proposed for butterflies prior to the twentieth century now rest and must be allowed to rest on the deductions of specialists concerning what might be termed accidents of history. The identification of syntypical specimens and the selection from them of suitable lectotypes has been a major preoccupation of revisionary authors, with no end yet in sight. And what fascinating snarls have been revealed, when digging to bedrock for "origins"! Occasionally, even the apocryphal rumors and gargantuan tales of the earlier giants have to be given some weight when tracing material, as witness the stories of Herman Strecker's high silk hat.

It becomes painfully clear how large is the role of historical happenstance in shaping nomenclature when it is recalled in terms of concrete examples. A classic one of course is the handling of the W. H. Edwards collection. How often students find themselves wishing that this material could have been preserved exactly as Edwards arranged and labeled it when it was in his hands, at Coalburg!

Which reminds me that in a small way I was involved in an

analogous history. Therefore I believe it is a duty to recount what I can remember of the handling of the J. D. Gunder series of argynnid butterflies after they came to The American Museum of Natural History in New York.

A number of things were evident at that time, merely from Gunder's personal arrangement of his specimens. These were details which became obscured or lost when the series were shuffled from their original ordering and incorporated into the Museum drawers. I recall in particular several oddities of interest to *Speyeria* students. For one thing, the taxonomic status of *Argynnis pfoutsii* Gunder (1933, p. 171) appeared to me then in a light which no future reviser ever could be expected to apprehend, as I shall explain. Also, a few questions were raised which to this day remain unclarified.

As a visiting guest I had no part in policy making, but as a bystander I was impressed by the solicitude of Michener, Klots and dos Passos as they discussed how best to conserve the values and potential in the Gunder material. It was an amusing bylight, too, I thought, that Lutz, who at that time was chairman of the Department, seemed to be indifferent to the whole affair. His passion was for experimentation, probing the physiological and other biological attributes of insects; one might say he was very modern in his contempt for the mere "collecting" of dead butterflies.

The burden of guiding decisions thus fell mainly on dos Passos and Klots. It must not be assumed that they were insensitive to the value of the Gunder Collection purely as an historical monument. It is doubtful if any of our students who are under fifty or sixty years of age can really sympathize with their dilemma. One would have to be able to evoke the historical "then" and one would have to have lived through the period to know and understand just how incredibly far the study of Nearctic butterflies has progressed since that relatively short time ago.

In retrospect, this seems to have been a turning point. Butterfly classification had evolved mainly from odds and ends, and even singletons, acquired at random as chance had afforded, usually bearing such edifying labels as, e.g., "Oregon Territory". The people then recognized as specialists and "best authorities" were laboring under a handicap beginning to be felt but impossible to overcome. Geographically representative series

simply did not exist. There was no possibility of examining region-to-region intergradings and discontinuities, much less to examine them for sympatrisms or to spin theories of their correlations with late Pleistocene refuging and ecogeographic factors.

Gunder may not have been the first to realize this need, but it can be emphasized that he was certainly the leader at the time, in this field of attempting large-scale geographic coverage. It was his vision and industry which Klots and dos Passos determined to carry forward and amplify. Nobody should fault them for scattering these particular bones of history. They broke up Gunder's arrangements, true, but only to lay the foundations of one of the great study collections of North American butterflies. I think they did the right thing; I lived in the era, too, and can remember how imperative our needs were, for better coverage, for continental surveys.

Reasonable care was exercised to keep the material in order. Every specimen was ticketed to identify its derivation from the Gunder Collection. Specialists were consulted before the plaques were opened and their contents dispersed. The fact of the specimens being in the the book-type Riker Mount cases, on cotton, was of course one of the major factors prompting the decision to rework Gunder's material. The papered excess was spread for later incorporation. The type specimens of taxa authored by Gunder were taken into the Museum's type collection which is maintained separately and given special care. This left the plaques, which Gunder considered to be his collection proper.

Dr. dos Passos invited me to help him pin and reclassify the "*Argynnis*", for three reasons: (1) We were then planning a jointly authored revision of the Nearctic species of these butterflies. (2) And prerequisite to this we had to rearrange and make usable the then-chaotic Museum collection, incorporating with it the extensive Gunder series. (3) Also, it seemed desirable that we should share responsibility of preserving whatever taxonomic or other data or deductions might appear from the original plaque arrangements and sortings. As I recall, we spent something like ten full working days merely to shuffle to a "species-by-States" arrangement, before any "study" could be possible. Incidentally, a recent (1969) check indicates that the geographic order has been maintained despite considerable additions. Students who go here and are given

instant access to whatever may be available of particular series from particular areas should realize the debt they owe to people like Gunder, Klots, dos Passos, and to the present Curator, Dr. Rindge, who keeps the series in scrupulous order and has added largely from his own field collecting.

Even so, and with all the work which has been done to ease the labors of researchers, I had a unique and never-again opportunity to see things which are now beyond recall. I saw precisely how Jeane Gunder interpreted taxa and categories, and I think it is long past time that somebody should speak up and defend his abilities. He seems to be remembered principally as a trifler with "aberrations", an arch-splitter. Few students seem to have any idea of his true dimensions as a pioneer. I noted instance after instance wherein he had lumped or juxtaposed taxa then rated as separate entities. The sheer size of his accumulations witnessed more eloquently than he, himself, ever managed to explain, of the importance he attached to geographical variation and of his concern to extend coverage to include generous population samples from as many localities as possible. Eastern lepidopterists, seeing this collection for the first time, were introduced to butterfly study in a new dimension; it was quite a jolt to some of them who had dismissed Gunder as a wild amateur.

I can testify for the argynnids that Gunder's arrangements bespoke not only his appreciation of the basic needs for extensive comparisons, but also a great deal of research in the literature and the study of preserved type series. His taxon usages in the main were up to present standards but naturally some of his ideas of "species" now seem outmoded. There is no need to eulogize him unduly; he made his share of blunders, and misdeterminations, and, as amply proclaimed by his critics, he wasted a disproportionate amount of energy in futile attempts to give nomenclatorial status to aberrations and minor color forms.

On balance, however, he surely deserves more credit and appreciation than seems to have been accorded him as one of our leading authors. The labels he put under his collection series I would say revealed a better grasp of identities and entities than can be claimed for any argynnid student prior to his time. They resulted, I am sure, from painstaking study combined with a really formidable taxonomic intuition. As for his blunders, one suspects that future workers will find

that "me and thee" also have sinned: it is impossible to work through any large collection without coming across the occasional lapses from virtue such as happen to us all. It is hardly fair to charge the man with errors which were, so to speak, inherent and embalmed in the listings and concepts of his day; leaving these aside only the few mistakes detailed in following paragraphs were noted, to which will be added my personal appraisal of their historical origins.

Gunder has been charged with one major taxon-error, namely, his misapprehension of *Argynnis platina* Skinner (1897, p. 154). I was in a position to understand how this error arose, since I had visited the Academy of Sciences and had studied Skinner's Utah material, shortly after Gunder had been there for the same purpose. Thus, I am safe in presuming that Gunder saw exactly what I did, in the way of Skinner-labeled material. It thus seems evident that he merely accepted, on Skinner's authority, that the variation range in Skinner's "*platina*" included forms which we now relegate to another species. It may as well be admitted that Skinner's legacy is a confused one; he apparently was unable to separate his own "*platina*" from his own *utahensis* (1919, p. 216). I recognized that his series were badly mixed and had the good fortune to be able to check my concepts with Nabokov; the latter had been collecting in Utah, had a good eye for species discrimination, and had been looking into these questions through spot-locality comparisons of sympatrisms, extent of local variation, etc. We agreed that Skinner never did learn to separate the Utah argynnid.

But Gunder tripped over Skinner's mistakes, with the result that he took away the impression of "*platina*" as applying to "*utahensis*". Then, in a very interesting display of taxonomic virtuosity, Gunder thereafter consistently applied "*platina*" in the erroneous way he had apprehended. Thus it came about that Gunder's plaque of "*platina*" was filled with Idaho greenish-disk *egleis* (Behr) ("1863": 1862, p. 174) of the sort which dos Passos and I later dubbed "*linda*". Knowing this much of the story it is clear that Gunder would assume one of the major elements in Utah argynnid variation to be nameless. Hence, his description of "*pfoutsii*", justifiable by all that he had been able to learn of types and of natural populations.

In this instance one sees again the prime importance of background data when assessing nomenclature. Granting the above bylights on "*pfoutsii*" an adjudication of its status follows inevi-

tably: it drops to synonymy, naturally, but it should be of interest also to know that it does not represent mere ignorance or a propensity to split, on Gunder's part, but is rather a wholly excusable mistake with a logical historical cause.

Another incongruity in the Gunder series, one I have kept in mind over the years, was the occurrence in Nevada-labeled material (Clark and Lincoln Counties, *leg.* Eugene Schiffel) of specimens obviously representing subspecies of *atlantis* (Edwards) ("1862": 1863, p. 54) and of *hydaspe* (Boisduval) (1869, p. 60). These were of facies suggesting derivation from Montana or perhaps British Columbia. The geographic association seemed rather weird, even then, at a time when very little was known of distribution. Even today it might be risky to aver precisely what does or does not occur around the Spring Mountains area in the way of *Speyeria*. However, from everything presently witnessed and conceived, this bears the earmarks of some preparator's mistakes. I mention it to ease the minds of investigators who may run across these specimens in the Museum. It seems best agreed that whoever will accept these records as authentic should bear the burden of proof. Quite likely they resulted from some scrambling of envelope data but at any event this probable boo-boo involves merely the geographical labeling, and not taxon confusion. But another incongruity I took note of seems to involve a little of both, who knows?

The plaque of *Argynnis whitehousei* Gunder (1932, p. 279) consisted of 3 males and 5 females identifiable as an *aphrodite* (Fabricius) (1187, p. 62). But in the same plaque were 8 males of an *egleis* subspecies (my identification). These latter were in a facies which would have been tolerable if they had been labeled as from "Utah", instead of as from "British Columbia". They were doubly suspect to me also since I did not know then and still do not know of any authentic British Columbia records of *egleis*, this being a species which seems to taper off to rarity in northern Montana.

I offer no guaranteed solution to this strange action of Gunder's; probably it is best to treat it as an unresolved mystery, which, in any event, is the present state of knowledge *re* northernmost distribution of *egleis*. Still, it is tempting to express my suspicions, since they might provide another lead in case that Canadian students should fail to find *egleis* after due search in the indicated region: I can vouch for the fact

that Tom Spalding supplied Gunder with some material; I learned this from my correspondence with both of them. From the appearance of these specimens in question I have reason to guess that they might have derived from the Provo region of Utah, which Gunder's involvement with Spalding would rationalize. But as it stands they are purportedly from Jaffray, B. C., August 1-5, 1929, *leg.* Whitehouse. It is very definite, then, that Gunder was guilty here of one of his rare lapses, making that most embarrassing of all taxonomic mistakes, namely, confusing things distinct in nature. To top it off, I fear he had another visit from the scramble-gremlin which misplaces geographical labels on spreading boards. At least, the question must be answered: What actually does occur in the vicinity of Jaffray, in the way of an *egleis* subspecies?

In summary, then, many values were lost when Gunder's "*Argynnis*" were removed from their plaques. Today undoubtedly we would photograph them before tampering. The fact remains, however, that these specimens, vastly enriched by later additions, have served the true purpose intended by Gunder and still remain fully accessible to interested students in the precise but expanded concept and vision of Gunder, which was to build toward a total view of North American butterfly speciation and subspeciation. Unfortunately, the thing which was lost in the process was an intangible vignette of Gunder himself, as reflected by his handwork.

At this late day, the only amend possible is to affirm for what my personal opinion may be worth that Gunder had rare natural talent as a taxonomist despite popular impressions to the contrary. I had the privilege of seeing for myself that his competence in sorting argynnids was quite amazing; very few students even today can approach his abilities in this department. And those who can remember what it was like, back in that quite recent and yet curiously remote era, to confront Western *Speyeria en masse* — we, at least, know very well the debt we owe to Gunder.

Merely from his sortings, innumerable instances could be cited of his acuity. Referring back to the blunder in the *whitehousei* plaque for example, one still could note how unerringly he had fingered out the *aphrodite* variation in the remainder of his British Columbia material, even from localities where *aphrodite* runs excruciatingly parallel to other species. In this and in many other instances of an analogous nature, his accurate

separations of parallel sympatres have stood unmodified over the years in the face of inspection by students with far larger data than ever were available to Gunder. He stood unmatched among his contemporaries; he was a far better argynnid taxonomist than McDunnough, for example, as can be seen from the historical record: McDunnough blundered seriously with some of the Western Canada parallels, even to the extent of assembling a mixture of entities in type series! My personal debt to Gunder is no small one. Dr. dos Passos and I became heirs to all of his extensive preliminary work with argynnids, and, as it has turned out, could have found no better source of properly sorted and correctly identified material.

Additionally, students should bear in mind that Gunder's approach to difficult genera was altogether modern although practically new and unheard of at the time. He first assembled huge and geographically representative material, which he attempted to sort out to "species", with a shrewd eye to sympatrisms and to variation as correlated with geographic barriers and opportunities for dispersals. In the case of the genus *Euphydryas* he went even further, to synthesize all of these facts with the evidences of genitalic structures. Indeed, his 1929 revision of the latter genus remains to the present day one of the landmark papers which have shaped our modern classification and concepts of butterfly species.

Given more time, it is altogether probable that Gunder would have revised "*Argynnis*" along the identical lines followed by dos Passos and myself. It was clear that he was quite far along in the data-gathering stage, and that he would have made short work of the ninety to a hundred and twenty-five or so "local species" then cluttering our lists and manuals. It cannot be repeated often enough that this man was not a splitter. He was a synthesizer, born before his time. We had no difficulty in following his ideas as expressed by his collection arrangements, and found relatively few puzzles and contradictions other than those described herein which seem mostly due to scrambled data. So, for argynnids, what with Gunder's published descriptions and the careful preservation of his specimens at the American Museum, there is little for future historians to stumble over, it would appear, if they will steer away from the superficial and altogether false presentation of Gunder as a playboy amateur.

Among other misfortunes which dogged Gunder, there remains

a major canard which seems to pass unanswered. Speculations continue to circulate that he did not do the work on *Euphydryas*, that it may have been the product of a hired collaborator. Before the obscurity of years closes over this latter revision it is a matter of urgency that any of the older generation having recollections or letters bearing on this subject should publish them. This is clearly an instance wherein "trivialities" might prove to have major historical importance. One fact seems assured: None of the original dissections or drawings were included in the material purchased by the Museum.

I know of no helpful data which might apply to this riddle. I exchanged relatively few letters with Gunder and in them there were no mentions of genitalic studies and only a few references to Western *Euphydryas* problems. Therefore, my personal curiosity, and I am sure the curiosity of other students, remains unsatisfied. We have a natural desire to know something of Gunder's methodology, of the material he assembled and his understanding of it. We have a duty to future researchers who will be equally curious. But as it stands, our estimation of the 1929 *Euphydryas* revision as a brilliant achievement seems best enforced by the fact that nobody seems able, even with vastly expanded material and knowledge, to come up with a better synthesis.

Are we never to learn more of the background of this mysterious feat? Perhaps, then, I should make bold to offer a comment which may have some incidental bearing on it. I know nothing about *Euphydryas*, but I did see how splendidly Gunder was brushing through the utter confusion which then prevailed in argynnids. From that experience I know that Gunder had an innate gift, a brilliance denied or only grudgingly recognized by his critics. Thus, I would be willing to defend the idea that Jeane Gunder needed no hired talent to supplement his own genius. Whoever can tell us more should do so.

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ESTIMATION OF NATURAL MUTATION RATES FOR ALBINISM IN TWO SPECIES OF THE SATYRID GENUS *CERCYONIS*

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IN THE PAST DECADE OF FIELD WORK and laboratory research with the woodnymphs of the Nearctic genus *Cercyonis* (Satyridae), I have had the opportunity to collect data on the frequency of various mutant genes within the four species: *C. pegala*, *oetus*, *sthenele*, and *meadi* (See Emmel, 1969, for taxonomic summary).

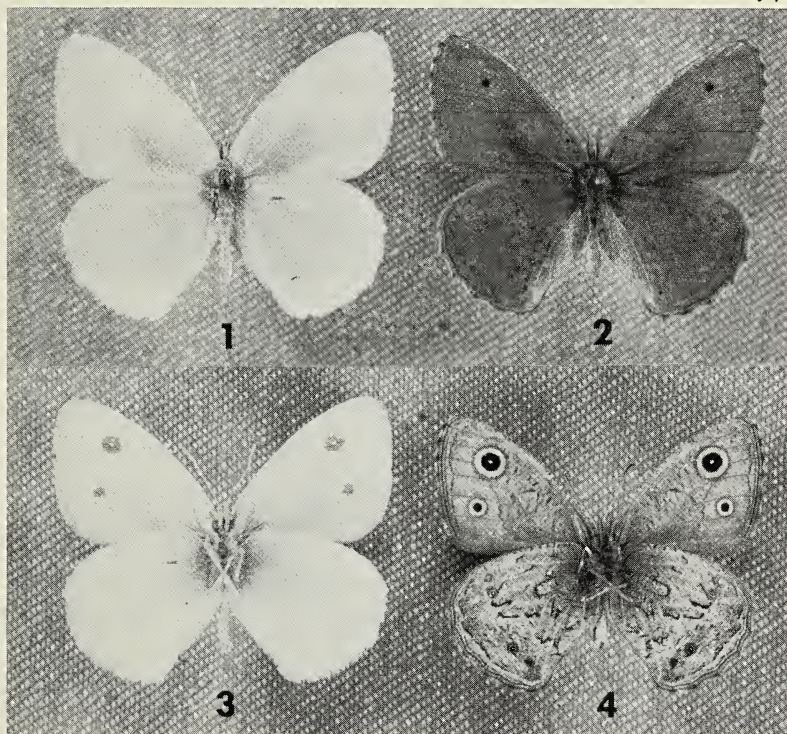


Fig. 1-2.—Dorsal surfaces of albinic and normal male specimens of *Cercyonis oetus* from a population in the Reese River Valley, Lander County, central Nevada.

Fig. 3-4.—Ventral surfaces of same specimens.

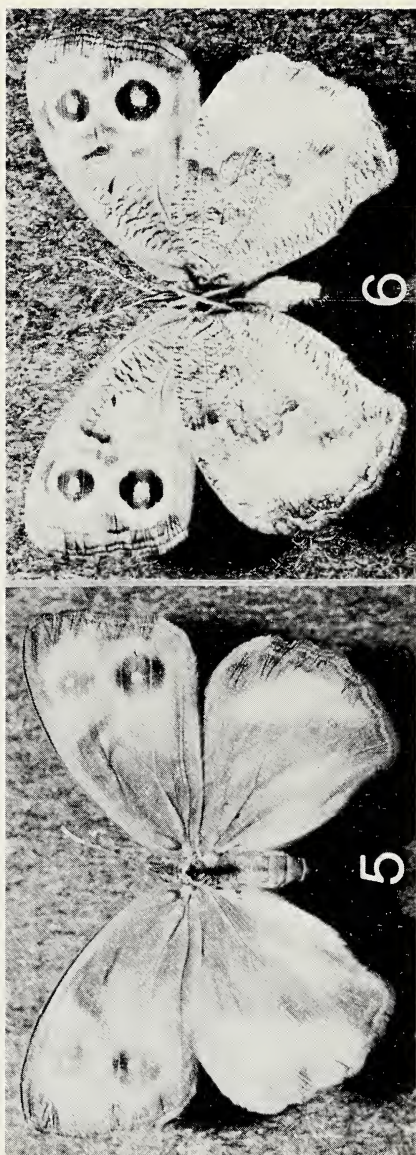


Fig. 5-6.—Dorsal and ventral surfaces of partially albinic female specimen of *Cereyonis pegala* from Boardman, Morrow County, Oregon.

An additional point is that spontaneous mutant specimens are probably eliminated from the populations largely by mate selection. Brown females undoubtedly refuse strange-looking *white* males (e.g., see Sheppard, 1961) and brown males most likely fail to approach white females as being of the "wrong" species.

I. *Cercyonis oetus*

On July 12, 1969, a totally albinic male *C. oetus* was taken by John F. Emmel in a population of brown specimens located four miles northeast of the Reese River on Highway 2, 5700 feet elevation, west-southwest of Austin, Lander County, Nevada. The dorsal and ventral surfaces of this specimen are compared with the normal male phenotype of this population (itself being extraordinary; see Emmel and Emmel 1970) in Figures 1-4. The only significant departure from complete lack of pigment is in the forewing ocelli, which are light brown instead of the usual black. The specimen is in essentially freshly emerged condition.

II. *Cercyonis pegala*

A partially albinic female individual of *Cercyonis pegala* was collected on the west side of the town of Boardman, 200 feet elevation, in Morrow County, Oregon, on July 11, 1964, by Edwin M. Perkins and Stephen F. Perkins. In this specimen, the albinic portions are mainly restricted to the outer half of each wing (but both surfaces).

DISCUSSION

One can calculate an approximate rate of spontaneous mutation for the expression of albinism by dividing the number of known mutant individuals by the total number of individuals observed. I have personally examined or seen in the field more than 12,000 individuals of *C. oetus* and more than 6,000 individuals of *C. pegala*, at a conservative estimate. With respect to albinism, the two specimens reported here are the only mutants I have seen. A number of other lepidopterists with many years in the field confirm these observations, adding still more to the base number observed for each species.

Thus we can estimate the probable maximum natural mutation rate for albinism in the two species, within an order of magnitude, as:

Cercyonis oetus 10^{-5} (.00001)

Cercyonis pegala 10^{-5} (.00001)

These figures, of 10^{-5} per gene per generation, are in the same

order as those known for *Drosophila* and man (Dobzhansky, 1951, p. 59) and for the domesticated silkworm, *Bombyx mori* (Tazima, 1964, p. 179-180).

Only two mutations involving albinism have come to my attention, and the purpose of this note is to provide an estimation for the spontaneous rate of mutation for this character in two species of these satyrids.

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NOTICES

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WANTED:

Brephidium exilis, *B. fea*, *B. isophthalma*. Life material and specimens for distribution study. Roy Jameson, 2429 Wordsworth, Houston, Texas 77025.

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THE JOURNAL OF RESEARCH ON THE LEPIDOPTERA

Volume 8

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DEVELOPMENT OF THE MARKINGS ON THE PUPAL WING OF *PIERIS RAPAE* (PIERIDAE)

JOHN M. KOLYER

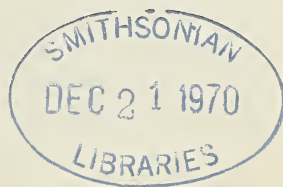
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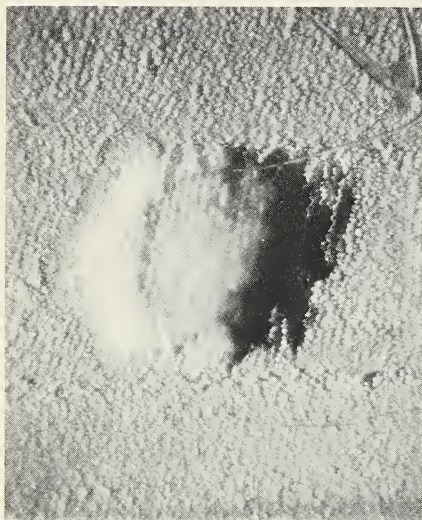
INTRODUCTION

THE DEVELOPMENT OF THE BLACK MARKINGS of *Pieris brassicae* (L.) was studied by Onslow (1916), who reported that the pupal wing became black all over when soaked in tyrosine solution while selective darkening of the markings occurred in tyrosinase solution. (The action of an oxidase, eg. tyrosinase, on a colorless chromogen, e.g. tyrosine, is known to give melanin pigments.) The conclusion was that the chromogen first was deposited in the areas destined to become black, then oxidase was supplied by the hemolymph, and finally atmospheric oxygen reached the surface of the wing and caused darkening where chromogen was concentrated. This explanation was modeled after that of Gortner (1911a) for development of the color pattern on the elytra of the Colorado potato beetle.

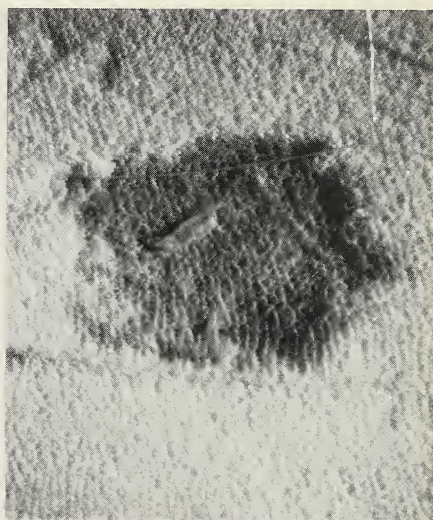
In contrast to Onslow's result, Braun (1939) found that "artificial pigmentation", i.e. selective darkening of the markings, occurred when pupal wings of *Papilio ajax* (L.) and *Ephesia kühniella* (Zeller) were soaked in tyrosine solution. Braun's explanation was that the darkened scales were less chitinized due to slower development and so were able to absorb the tyrosine solution. His conclusion was that oxidase is present in the scales in general, but at the "certain time of development pigment is present in the body" only the soft, less chitinized scales are able to accept this "pigment" (chromogen).

The general problem of development of the wing pattern in Lepidoptera has received study by Kühn, Goldschmidt, Köhler, and others, as reviewed in detail by Caspari (1941). Brief summaries are given by Wigglesworth (1965: 78) and Bodenstein (1953).

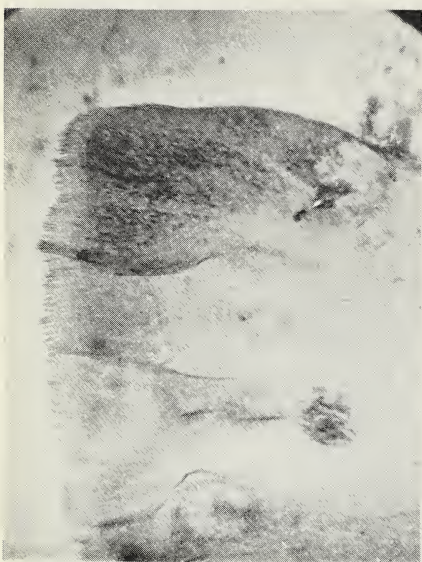




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PLATE I

Fig. 1 (upper left) — Upper spot of wing from pupa (♀) about 175 hours old, showing "relief" effect. The illuminating light beam was 10° from the horizontal to give shadowing.

Fig. 2 (upper right) — Upper spot of wing from pupa (♀) about 195 hours old, with markings in early stage of darkening. Lighting as in Fig. 1.

Fig. 3 (lower left) — Artificial pigmentation of wing from 190 hour old pupa (♂) by aqueous extract of hemolymph (details in text).

Fig. 4 (lower right) — Artificial pigmentation of wing from 190 hour old pupa (♂) by undiluted hemolymph (details in text).

The object of the present work was to study pattern development for *Pieris rapae* (L.) in order to contribute original observations as well as to evaluate the explanations of Onslow and Braun.

EXPERIMENTAL

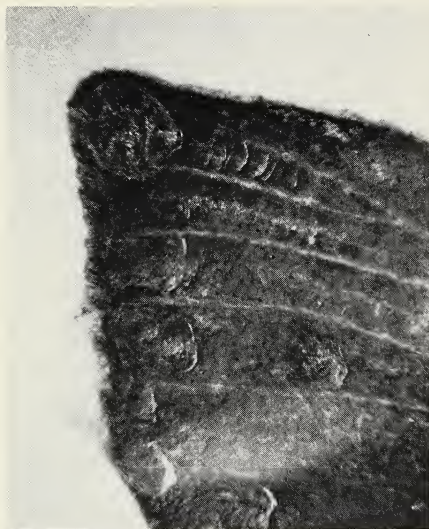
Source of pupae — Final instar larvae were supplied by the U.S. Department of Agriculture (see Acknowledgement). These had been reared on an artificial diet at $26 \pm 1^\circ\text{C}$ and $45 \pm 5\%$ relative humidity under continuous cool white fluorescent light. Development was completed on cabbage leaves from refrigerated heads. Pupae were kept in a room at $70\text{--}80^\circ\text{F}$ and 28-35% relative humidity.

Dissection techniques. — Early pupae, e.g. 90 hours old, presented more of a problem in removal of the forewing than did pupae at later stages, after the wingcases had whitened at about 135 hours. However, a successful procedure was to cut off the head end of the pupa, just at the base of the wings, by pushing downward with a razor blade. Then a small pair of scissors was used to cut all around the wingcase. The wingcase was placed on a table inside up, a small piece of blotting paper was used to remove matter (including the hindwing) covering the forewing, the nail of the left index finger was applied to hold down the basal end of the integument, and the wing was grasped at the base with pointed forceps and carefully peeled off to be placed in water or aqueous solution.

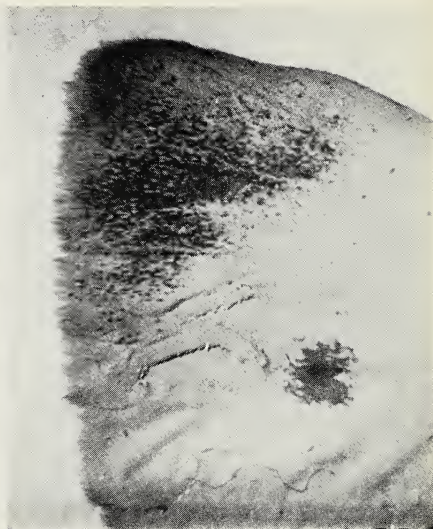
As the time of eclosion drew near, it became possible to dissect out the forewings merely by cutting the pupal case and pulling the wing out by the base.

The wings shown in Plates I-III were allowed to dry in air, and each was mounted on a microslide on a square of white blotting paper under a cover glass, the latter being held in place by a gummed label with appropriate hole. The photographs were made through a 100X microscope for Figures 1 and 2, a 1000X microscope for Figure 8, and a 16X microscope for the other Figures.

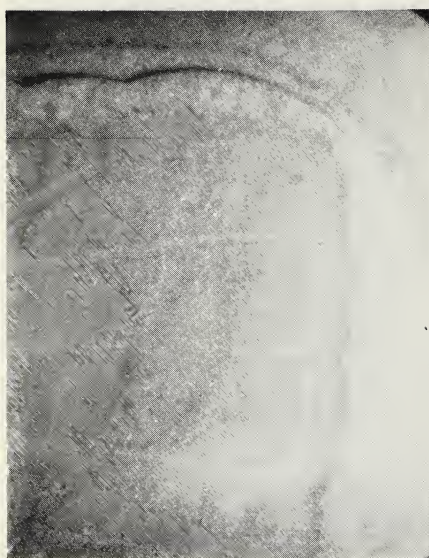
Observations. — Most of the observations were made with a stereo microscope at 16X. Illumination was a concentrated spot of light from a microscope illuminator aimed down on the subject at a 45° angle. Features of the wing such as venation and areas of translucent scales were seen most clearly against a background of black felt, but judgment of degree of darkening



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PLATE II

Fig. 5 (upper left) — Wing from 160 hour old pupa blackened by exposure to dopa solution followed by drying in air (details in text).

Fig. 6 (upper right) — Artificial pigmentation of wing from 185 hour old pupa (♀) by dopa solution (details in text).

Fig. 7 (lower left) — Control wing (in water) for wing shown in Fig. 6.

Fig. 8 (lower right) — Dark scale from the spot of a wing from a 175 hour old pupa (♀), artificially pigmented by dopa solution (details in text). The scale was mounted in Permout (Fisher Scientific Co.) and photographed by transmitted light through a microscope with 10X wide-field ocular and 100X achromatic objective (1.25 N.A., oil immersion).

of scales was made against a white background. Close observation of the scales was made with a biological microscope at 100X or 430X with either reflected or transmitted light or at 1000X (oil immersion) with transmitted light.

Wings were soaked conveniently in solutions in uncovered watchglasses at room temperature (70-80°F) for a few hours, but longer times required closed containers to prevent evaporation.

Solutions and reagents.—

Saturated tyrosine solution: Excess L-tyrosine (Matheson Coleman and Bell) was shaken with deionized water. The concentration is reported to be 0.045% at 25°C (Anonymous, 1960).

Dopa solution (0.5%): In 20 ml deionized water was dissolved 0.10 grams of DL-3-(3,4-dihydroxyphenyl)alanine (practical grade, Matheson Coleman and Bell). The solubility of the less-soluble L-form is 0.5% (Anonymous, 1960). A 0.4% solution was used by Gonnard and Svináreff (1951) as substrate for potato tyrosinase.

Iodine reagent: According to the method of Campbell (1929), a solution of 1.2 grams iodine and 1.6 grams potassium iodide in 1.5 ml water was added to 50 grams of 20% acetic acid to give a clear, dark-red solution.

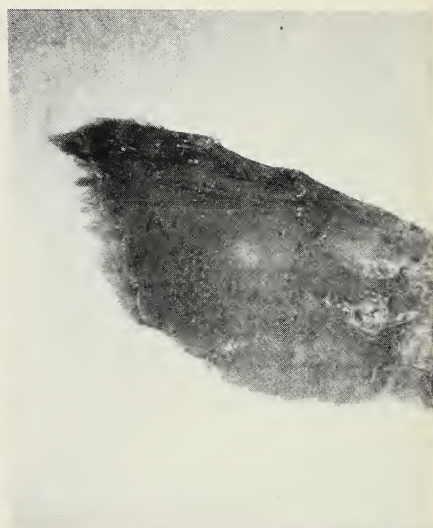
Tollen's reagent: Small portions were prepared according to Feigl (1954) and used immediately (the solution cannot be stored as it decomposes and deposits explosive silver fulminate). A convenient amount (about 0.6 ml) was given by adding 5 drops 10% sodium hydroxide to 5 drops 10% silver nitrate to give a brown precipitate and then dissolving this by addition of 3 drops of a mixture of equal volumes conc. ammonium hydroxide (28-30% NH_3) and water.

Le Rosen formalin reagent: Since the reagent cannot be stored, a small volume was prepared just before using by stirring 2 drops of 37% formaldehyde solution into 10 drops conc. (98%) sulfuric acid in a watchglass. This is a variation (higher formalin content) on the reagent according to Feigl (1954).

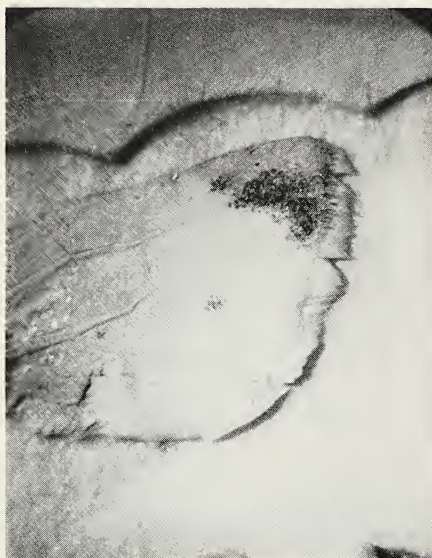
Misc. solutions: Concentrations are given in weight-%, e.g. 50% sulfuric acid was prepared by adding 50 grams acid to 50 grams water. The water used was always distilled and then deionized. 4-Chlororesorcinol (Koppers Co.) was recrystallized to give capillary melting point 108.5-110°C. The other organic compounds were used as supplied by Matheson Coleman and Bell or Eastman Organic Chemicals.



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PLATE III

Fig. 9 (upper left) — Wing from 175 hour old pupa (♀) soaked in oxygen-free dopa solution (no pigmentation occurred) and then allowed to dry in air (markings darkened; details in text).

Fig. 10 (upper right) — Wing from 189 hour old pupa (♂) tinted deep pink by murexide formation (details in text). The spot (pale yellow) is faintly visible in the photograph.

Fig. 11 (lower left) — Wing dissected from pupa (♂) with markings just beginning to darken; shown after 18 hours in water-saturated air.

Fig. 12 (lower right) — Control wing (18 hours in water-saturated nitrogen) for the wing shown in Fig. 11.

RESULTS AND DISCUSSION

1. Structural Changes During Development

Chronology of development. — The following notes on scale development are preliminary observations based on a few dissections. Times from pupation (final larval molt to give pupa) are approximate and intended to be typical; some pupae developed more slowly.

27 hours: Careful dissection gave a tracheated wing with frothy appearance at 430X. This seemed to consist of epithelium with scales not yet grown. The wing epithelium of the freshly-molted *Pieris brassicae* pupa is composed exclusively of stem cells which later give the scale and socket arrangement (Lipp, 1957).

87 hours: Scales covered the wing. These were round, generally about 0.02 mm in diameter but some larger.

101 hours: Scales were generally round, approx. 0.04-0.09 mm in diameter. Staining with 1% crystal violet (Colour Index No. 42555) in 95% ethanol or with a 1:1 mixture of saturated safranin O (Colour Index No. 50240) in 95% ethanol with aniline water (Shillaber, 1944) helped make the scales visible.

122 hours: Hairlike fringe scales on the margin were conspicuous against a black background. Scales on the wing were of various shapes, some round, usually with a point, others somewhat elongated with three teeth. Length varied from about 0.04 to 0.14 mm. The impression was that some of the round scales grow into the elongated form, length about 0.13-0.17 mm, that is most common on the adult wing. Exposure to tyrosine or dopa solutions darkened the scales and improved visibility at 100 or 430X.

135 hours: The wingcases became noticeably whitened to the naked eye. Also noted was disappearance of the former translucency of the pupa in the wing region when viewed from the side against a source of light.

165 hours: The future markings (spots), though not at all pigmented, were dimly visible through the pupal case.

175 hours: Female wings had a yellow appearance as viewed through the pupal case.

195 hours: Darkening of the markings began. The most slowly developing pupae reached this stage in 220 hours.

200 hours: Markings were completely darkened. The darkening process required 4-5 hours at 80°F. The wings shortly later became hydrophobic whereas in earlier pupae they were

easily wetted when dissected and placed in water.

220 hours: Eclosion.

Ages of pupae given below were adjusted in some cases in order to indicate point of development in terms of the above schedule.

Visible distinction of future-black scales. — The future-black scales in the apical area and, particularly, in the spot(s) (one on male, two on female wing) became noticeably different in appearance (glossy by reflected light at a certain angle, translucent by transmitted light) at about 135 hours. A good description is "like spots of grease upon white paper" (Onslow, 1916). At 155 hours the scales all collapsed against the membrane when the wing was dried in air, but at a later time, e.g. 175 hours, a "relief stage" (Braun, 1939) became obvious after air-drying for only a few minutes. With side-lighting, the spot scales appeared to have collapsed against the wing membrane while the surrounding scales remained erected. An example is shown in Plate I, Figure 1. This effect was no longer well-defined on a pupal wing with markings just beginning to darken (Plate I, Figure 2).

2. Artificial Pigmentation

Water and saline. — In no case among the many forewings exposed to water did darkening occur in times up to 6 hours, but at 37 hours (pupa 173 hours old) there was darkening (brownish color) at the base and very slight darkening of the future-black scales, the rest of the scales remaining the original white. The other wing of the 173 hour old pupa was exposed to 0.05 M sodium chloride for 37 hours with no darkening. However, a wing from a 190 hour old pupa showed darkening at the torn base in 0.05 M sodium chloride at 9 hours, and the spot was very pale brown (wing itself very pale yellow-tan) at 48 hours. This NaCl concentration is in the general vicinity of the chloride content of the pupal blood, e.g. 0.02 M in chloride for the *Pieris brassicae* pupa (Buck, 1953). Onslow (1916) reported slight darkening of markings on the pupal wing of *P. brassicae* after 12 hours in "normal saline" (0.75% NaCl).

Hemolymph. — Hemolymph, as obtained in diluted form by grinding pupae with chloroform water and filtering, was reported by Onslow (1916) to give considerable darkening of the markings of the pupal wing of *P. brassicae* in 12 hours.

In the present work, diluted hemolymph was prepared from a 190 hour old pupa by grinding all but the forewings with 1.5

ml deionized water and filtering to give a colorless, opalescent liquid, in which one forewing was placed. The future-black scales were very pale brown after 33 hours vs. no appreciable darkening for the other (control) wing in deionized water. In another experiment, the wings were removed from a 190 hour old pupa, and the remainder of the pupa along with three pupae with markings darkened was ground with 6 ml water (pH 5.6) and filtered. Part of the filtrate (pH 6.6) was added to one wing, and the remainder was adjusted to pH 8.0 with several drops of 0.1% sodium carbonate solution and added to the other wing. The same procedure then was repeated using chloroform-saturated water. The result was that both water and chloroform water extracts gave light-brown future-black scales visible against the pale-tan future-white scales, but the water extract seemed to give slightly more darkening (Plate I, Figure 3). Results at pH 8.0 were not so good as at pH 6.6, especially for the chloroform water (negligible darkening of future-black scales). The pH of *P. rapae* pupal blood has been reported as 5.9-6.4 (Buck, 1953).

A drop of clear, pale-green hemolymph was noted to exude from the body of a 215 hour old pupa (markings fully darkened) from which the head end had been cut at the base of the wings. This liquid was placed on one wing from a 190 hour old pupa, and the other wing was placed in water as a control. After 5 hours some darkening of the markings of the wing with hemolymph was noted, and a small amount of water was added to prevent desiccation. At 10 hours the markings were well darkened in the hemolymph case (Plate I, Figure 4) vs. no darkening of future-black scales for the control wing. The contrast between markings and white scales was more pronounced (white scales less darkened) for the wing shown in Figure 4 than in artificial pigmentations with dopa solution.

Tyrosine. — Saturated tyrosine solution caused rapid blackening (in less than 30 minutes) at the edge of the torn base of the wing, as did 0.5% dopa, presumably because of the tyrosinase-containing hemolymph exposed in this area. For a 165 hour old pupa the markings (spot and apex) darkened slowly; the scales within the spot were pale gray after 6 hours. As a control, the other forewing from the same pupa was soaked in deionized water and showed no darkening after 6 hours.

Braun (1939) claimed that wings in tyrosine solution unfolded (expanded), a phenomenon produced by "no other solution tested". In the present work there was much individual variation in the extent of expansion, but all the aqueous chromogen solu-

tions, 0.05 M NaCl, and deionized water itself gave this effect. Using the distance from apex to outer angle (4-5 mm for untreated pupal wing, typically 14 mm in adult) as a measure of expansion, the following values were noted for pairs of wings from the same pupa: 11 mm for saturated tyrosine solution vs. 9 mm for water, 6.5 mm for 0.5% dopa solution vs. 7 mm for water, and 10 mm for 0.1% sodium carbonate solution vs. 12.5 mm for water (the greatest expansion noted). Pupal age may have a large influence on degree of expansion. Tyrosine solution obviously is not unique in causing expansion, and possible marginal superiority over water or other aqueous solutions would have to be demonstrated by a number of competitive experiments.

Dopa. — The use of tyrosine solution soon was discontinued in favor of 0.5% dopa, since the latter was found to be far superior for artificial pigmentation. For example, at 6 hours, one wing (from 124 hour old pupa) in dopa solution was well darkened (deep gray) while the other wing in tyrosine solution had only a light gray cast. This result would be expected because dopa is an intermediate between tyrosine and melanin (oxidation of tyrosine to dopa by tyrosinase is easily demonstrated — Evans and Raper, 1937), dopa is more sensitive to enzymic oxidation than many other chromogens (Schmalfuss, 1924), and dopa is even readily oxidized nonenzymically, e.g. the 0.5% solution begins to turn brown in a few days.

At 131 hours pupal age, dopa solution caused the whole wing to become light gray in 3.5 hours with no selective darkening of the future-black scales. At 160 hours pupal age, dopa solution after 1.5 hours caused a wing to become gray with no differentiation (except translucency) of future-black scales; after rinsing with water and air-drying overnight the wing was dark gray, almost black, with markings barely discernible (Plate II, Figure 5). At about 185 hours pupal age, exposure to dopa solution gave selective darkening that remained clear after the wing had been rinsed with water and air-dried (Plate II, Figure 6). The other (control) wing in deionized water did not darken (Plate II, Figure 7). Figure 8 (Plate II) shows a dark scale from the spot on a female wing (from 175 hour old pupa) which had been artificially pigmented in dopa solution for 1.5 hours. Minute spots of pigment are visible, seemingly within the sub-

stance of the scale as claimed by Onslow (1916), Reichelt (1925), and Braun (1939).

When exposure to dopa solution was continued, for a pupa about 190 hours old, the spot and apical scales were black against a dark gray background at 24 hours, and at 48 hours the wing was very dark gray, almost black, with markings barely discernible (resembling Figure 5 n Plate II). The white scales on the wing of a 204 hour old pupa, with markings recently darkened, became very light gray after 4.5 hours in dopa solution, and an even older pupa, apparently ready to eclose, gave the same result.

The indication is that in earlier stages, e.g. 160 hours old or less, all scales became pigmented at the same rate, while later on (185 hours old or more) the future-black scales darkened sooner but were eventually nearly equalled by the slower-darkening future-white scales. Artificial pigmentation with dopa thus is a "kinetic effect" resulting from the slower rate of darkening of the future-white scales, not their inability to darken.

Other chromogens. — Cresols (54% m-, 29% p-, 17% other phenols), DL-beta-phenylalanine, p-aminophenol, resorcinol, and catechol were tested as 0.5% solutions with the other wing from each pupa (about 170 hours old) in 0.5% dopa solution. At 3 hours, all the wings in dopa solution were gray with future-black scales darker gray. Phenylalanine and resorcinol gave no darkening, the cresol mixture gave an orange tint to the basal half of the wing but no darkening of future-black scales, p-aminophenol gave a tan-gray tint to the whole wing with doubtful darkening of the markings (translucency was difficult to distinguish from pigmentation), and catechol gave an overall orange-gray color with future-black scales darkened. These results agree with the literature. The tyrosinase of the *P. rapae* pupa oxidized catechol more readily than p-cresol (Pugh, 1934). Tyrosinase from the meal worm oxidized p-aminophenol but not resorcinol (Gortner, 1910).

Inhibition by chemicals. — Melanogenesis inhibitors (see Kolyer, 1966) were tested by adding at 0.5% to a 0.5% dopa solution, with the other wing of each pupa (about 174 hours old) in 0.5% dopa solution as a control (all turned gray with markings very dark gray in 3 hours). Thiourea and L(+)-ascorbic acid allowed no darkening of wing or markings, while the wing became light gray but with little darkening of the markings with hydroquinone or 4-chlororesorcinol. Thiourea has been shown to

cause pronounced inhibition of phenoloxidase activity in silkworm homogenates (Chmurzynska and Lech, 1963) and is a well-known melanogenesis inhibitor. Ascorboic acid is a melanogenesis inhibitor in vitro but is considered necessary in the diet for optimum development of the silkworm (Ito, 1961). None of these inhibitors prevented pigmentation when fed to larvae in earlier work with *P. rapae* (Kolyer, 1966).

When the test was repeated (pupae about 177 hours old) with the inhibitors (except hydroquinone) at 0.05%, i.e. 10% on the level of dopa instead of 100% as in the first test, the result was partial inhibition (markings darkened but less intensely than in the controls). Using pupae at about 193 hours old, at 0.005% inhibitor (1% of dopa level) there was little, if any, inhibition. Thiourea (at 0.5%) also inhibited darkening of the markings (pupa about 193 hours old) in 0.5% catechol solution for 3 hours, but the wing became pale orange-gray overall.

Inhibition by heat. — Gortner (1910, 1911b) reported that activity of tyrosinase from the meal worm or the periodical cicada is destroyed by heating at 75°C for one minute, and Onslow (1916) found that boiling the pupal wing of *P. brassicae* prevented darkening in tyrosine solution. This denaturation of the enzyme by heat was confirmed for *P. rapae* as follows. One wing from a 190 hour old pupa was placed in 1 ml water in a small test tube, which then was immersed in water at 88-90°C for 5 minutes. After 48 hours in dopa solution the wing was pale yellow with no darkening of the future-black scales, while the other (unheated) wing showed darkening of the future-black scales in 2 hours.

In a series of hemolymph tests, the body fluid was squeezed from three pupae (160 hours old) into a micro test tube, which then was heated in water at 88-90°C for 5 minutes. The resulting semisolid paste was diluted with 0.09 ml water and filtered by drawing into a pipet plugged with cotton wool, and the filtrate was applied to heated and unheated wings. Unheated, filtered fluid similarly was applied to heated and unheated wings. At 48 hours, the unheated wing with unheated hemolymph was pale tan with darkening at the torn base but no darkening of the markings. The unheated wing with heated hemolymph was gray-brown with darkening of the apex but not the spot. The heated wing with unheated hemolymph was tan with markings not darkened. The heated wing with heated hemolymph was pale orange-yellow with no darkening. Though the markings

in this series were not darkened when both hemolymph and wing were unheated, as they were in other experiments, general darkening of the wing was prevented only by heating *both* wing and hemolymph. This is in agreement with the data of Onslow (1916) and is explained by the presence of both oxidase and chromogen in the wing as well as in the hemolymph.

Role of oxygen. — The hemolymph, which contains both oxidase and chromogen, darkens when contacted with the atmosphere (Pugh, 1934, and Wigglesworth, 1965: 383). In the present work it was noted that darkening proceeded within a minute when pupal hemolymph diluted with water was sparged with fine bubbles of air.

In the enzymic oxidation of dopa, oxygen is necessary, though only a trace is required (Gortner, 1911a, and Schmalfuss, 1924). That dissolved oxygen was essential for the artificial pigmentations described above was indicated by soaking a wing (from 175 hour old pupa) in a 0.5% solution of dopa in essentially oxygen-free deionized water (prepared by boiling 10 minutes and cooling while bubbling in high-purity nitrogen). After 2 hours there was no darkening, even at the torn base, while the other wing from the same pupa in ordinary (air-containing) 0.5% dopa solution was blackened at the base and had the future-black scales gray. The oxygen-free wing was rinsed with water and allowed to dry in the air for 1.5 hours, during which time artificial pigmentation proceeded, presumably due to availability of oxygen (see Plate III, Figure 9).

3. Chemical Tests

Iodine solution. — Braun (1939) utilized a test (treatment with iodine solution, then zinc chloride solution) said to distinguish between "hard" and "soft" chitin and found for *Papilio ajax* and *Ephestia kühnella* that future-dark scales appeared light and future-white scales appeared dark. This result, according to Braun, "exhibits clearly that the different parts are found in different stages of chitinization". However, the test used by Braun is not necessarily a specific test for chitin (Richards, 1947). Also, the hardest cuticles often contain less chitin than the soft (Wigglesworth, 1965: 32). Richards (1947) treated *P. rapae* scales with hot alkali and applied the chitosan test (Campbell, 1929), which probably proves the presence of chitin when it is positive, as it was for the dark scales. The white scales were dissolved, but chitin in some cases is destroyed by hot alkali, so that the presence of chitin in the white scales could not be discounted.

In the present work, pupal wings were treated with iodine solution (see Experimental) as used in the chitosan test (Campbell, 1929). Chitin itself (Matheson Coleman and Bell practical grade, prepared by purifying crab shells) was stained dark brown by this reagent. For wings of pupae about 175 hours old the spot was orange against a pale orange background after iodine treatment, but translucency was a factor in this appearance. Addition of 10% zinc chloride gave no color change, but addition of 50% sulfuric acid caused rapid darkening of the wing with, in some cases, marked resistance to darkening by the spot so that it appeared as a "window". This may be the result of absence of pterin pigments in the future-black scales, because particles of leucopterin (from K & K Laboratories, Inc.) were stained brown by treatment with the iodine solution when followed by 50% sulfuric acid but not when followed by 10% zinc chloride. Thus, pterin pigment distribution rather than differences in chitinization possibly may explain the selective staining reaction described.

Murexide test. — The forewings from a 189 hour old pupa were exposed to chlorine gas for 9 hours and left in the air for 17 days. The wings, pink only around the edges, then were exposed to gaseous NH_3 for 5 minutes, during which time they became deep pink (rose color). The spots remained pale yellow against the pink background (see Plate III, Figure 10), presumably because the future-black scales were free of pterins such as leucopterin, xanthopterin, and isoxanthopterin, which give the murexide color (Ford, 1947, and Gates, 1947). Leucopterin, isoxanthopterin, and other pterins have been found in the *P. brassicae* pupa (Busnel and Drilhon, 1949, and Harmsen, 1966).

Ammoniacal silver nitrate. — The argentaffin reaction is used to identify o-hydroxyphenols such as dopa (Richards, 1953), which reduce the reagent to give free silver (black). Various solutions have been described, all containing the readily-reduced complex of silver ion with ammonia or amines. In the present work Tollen's reagent was found convenient.

Wings from 123, 125, and 131 hour old pupae were covered with fresh Tollen's reagent and within 5 minutes had turned faint brown with no differentiation of the spot (which does not become visible by translucency until about 135 hours). However, a wing from a female pupa about 175 hours old began to darken immediately and in 2 minutes was practically black with the two spots appearing as colorless "windows". The other

wing was soaked in water for 15 minutes before adding the reagent; the result was the same except that the wing darkened less (to brown rather than almost black). The wing from a 204 hour old pupa, with markings darkened, turned dark gray after 2 minutes in the reagent so that the markings were barely discernible. The same result was given by an adult wing (16 months old).

Selected white flakes of chitin were pale gray after 3 minutes in the reagent, while particles of leucopterin turned brown to black within 2 minutes. Urates, which are somewhat similar chemically to the ammonium salt of leucopterin presumably formed on adding Tollen's reagent, are said to give a positive argentaffin test (Richards, 1951: 71). Isoxanthopterin reduces Tollen's reagent (Gates, 1947).

Paper chromatography was done to verify the presence of pterins in the pupal wing. Extracts were prepared from adult wings (mixed sexes, washed with ether) or pupal forewings (separate extracts for male and female wings from pupae about 190 hours old) by soaking the wings in 20% ammonia solution for a few hours. The extracts were chromatographed vs. a solution of leucopterin in 20% ammonia on Whatman No. 40 filter paper by the ascending method (40 minutes at 78°F; solvent front ran about 64 mm above point of application of extracts). The solvent system was that of Partridge (1948) as recommended for pterins by Good and Johnson (1949). This was prepared by shaking 40 ml n-butanol, 10 ml acetic acid, and 50 ml water, allowing to stand 4 hours, and discarding the lower (aqueous) layer. After drying, the paper was viewed under ultraviolet light (mainly about 360 millimicrons). The adult wing extract gave two fluorescent spots: very pale blue, R 0.11 (Good and Johnson report 0.12 for leucopterin), and bright purple, R 0.28 (Watt and Bowden (1966) report 0.24 for isoxanthopterin). These same two spots have been reported for adult wings of *Pieris rapae*, *P. brassicae* and *P. napi* (L.). The pupal wings also showed these two spots as well as an additional spot, pale yellow, R 0.39, which was more intense in the female wing; Good and Johnson assign this (R 0.38) to xanthopterin. Tollen's reagent poured over the paper caused intense darkening of the spots of application of both the wing extract and the leucopterin, indicating that much of the leucopterin applied to the paper failed to migrate with the solvent.

The tentative conclusion is that the positive Tollen's test is caused by pterins and urates associated with the future-white

scales. The weaker test after exposure of the wing to water may have been due to partial extraction of pigment materials.

Formalin-sulfuric acid. — Le Rosen formalin reagent added to wings from pupae about 190 or 198 hours old caused red-violet staining along the veins to a distance of about half way out on the wing, which appeared clear pale-yellow. A fragment of muscle tissue from the thorax showed red-violet streaks when treated with the reagent. Crystals of dopa dropped in the reagent also gave a red-violet color, as has been reported (Denigès, 1926). Catechol gave the same result, but L-tyrosine dissolved and then reappeared as a white precipitate, presumably the sulfate, without giving a color. A red-violet color is said to be given by phenols in general (Feigl, 1954). In the present instance the color is attributed to phenolic substances, such as dopa, in the hemolymph of the veins. No violet color in the region of the markings was observed. An interesting incidental effect was the clear display of the tracheae due to transparency afforded by the reagent.

Concentrated sulfuric acid, without formalin, gave no color, nor was rapid dissolution of the scales observed as described by Braun (1939). Incidentally, a technique for isolating the wing membrane was provided by exposing the wing to the acid for 5 minutes followed by a water rinse. It was then easy to push away the scales as a soft mass.

4. Natural Pigmentation

Some experiments were performed to evaluate the suggestion of Onslow (1916) that pigmentation is triggered by exposure of the wing surface to air. When pupae with markings just starting to darken, or even half-darkened, were placed in nitrogen, either dry or saturated with water vapor, pigmentation was arrested. Results with isolated forewings were consistent. The forewings were dissected from a female pupa with markings judged just about to darken and placed in separate vials, one filled with nitrogen and the other with air. A drop of water was present in each case to saturate the gas and prevent desiccation. After 7 hours the markings of the wing in air were about half darkened, while no darkening had occurred in nitrogen. In a similar experiment, male forewings, originally slightly darkened, were left in humid air vs. nitrogen for 18 hours. The result was further darkening in air vs. no change in nitrogen; see Plate III, Figures 11 and 12.

The pupal case was removed from one wing of a pupa with markings half darkened. The imago eclosed 14 hours later with markings fully darkened on the wing that had remained covered but arrested at half darkened on the wing that had been exposed. In a similar experiment, the markings were just starting to darken when one wing was exposed. Again, the markings on the exposed wing failed to darken, while the markings on the covered wing were perhaps 75% darkened (in terms of final intensity) after 4 hours.

Since the above results were attributed to desiccation by evaporation of water from the exposed wing, pupae with the apex of the wing exposed were placed in vials containing cotton wool saturated with water to provide 100% relative humidity. For air, results (initiation of darkening, completion of darkening, eclosion), in hours from start of experiment, were: 13, 20, 25; 1, 5, 15; 0, 5, 19. For oxygen, results were: 19, 24, 36; 0, 7, 13. In all cases there was no difference at any time in appearance of the exposed vs. the covered apex.

Using two pupae with markings not yet starting to darken, the apex of one wing was exposed and covered with petroleum jelly in an attempt to exclude air from the wing surface. Approximate times (in hours as above) were: 31, 35, 38, and 22, 27, 31. In the first case no difference was observed during pigmentation of the apices, but in the second case there was a delay in pigmentation of the outer part of the petrolatum-covered apical marking. The fact that a delay was observed suggests that contact of the scales with air is a requirement, but the data of the preceding paragraph show that the apex can be directly exposed to air for 13 hours (or to oxygen for 19 hours) before pigmentation commences.

CONCLUSION

Artificial pigmentation. — Oxidase must exist in both future-black and future-white scales, since both eventually darken when chromogen, e.g. dopa, is supplied. But why is artificial pigmentation much more rapid for the future-black scales? Braun (1939) argued that these scales are "softer" and "less chitinized" but failed to prove chitinization of the future-white scales. Even if selective chitinization were demonstrated, the literature indicates this would not necessarily mean greater hardness and lower permeability. Alternative possibilities to greater permeability of the future-black scales are (1) less oxidase in the future-white scales and/or (2) inhibition of

melanogenesis in the future-white scales. The latter idea may have merit on the basis that considerable evidence was given by the chemical tests for the presence of pterins in the future-white scales and the substantial lack of these pigments in the future-black scales, and leucopterin, xanthopterin, and isoxanthopterin have been shown to have an inhibitory effect on potato tyrosinase *in vitro* (Gonnard and Svináreff, 1951, and Isaka, 1952).

The "relief stage" effect seems to indicate greater rigidity for the future-white scales, but there is no reason to assign this to "chitinization." Hardening of the protein of the walls of the scale, without chitin, seems as good a supposition since Richards (1947) failed to demonstrate chitin in the white scales of the adult *P. rapae*. It even seems possible that the white pigment itself could have a reinforcing effect by being deposited in the striations or corrugations of the scale.

In fact, the appearance of pigment at about 135 hours in the future-white scales might explain all the observations. The question then would revert to — What causes this selectivity of deposition of pterin pigments?

Whatever the explanation, artificial pigmentation seems only a relatively pale and less selective simulation of the natural process in which some scales remain pure white while others blacken intensely.

Natural pigmentation. — Braun states: "At a certain time in development pigment is present in the body and the subsequent dark parts, being still soft at this time, will deposit pigment". Presumably by "pigment" is meant chromogen. Also: "If at a certain time in the development tyrosine is present, it will only be deposited in those scales which represent a certain condition of the chitin at this moment, which means only a certain part of the pattern". However, tyrosine is found freely in insect blood (Brunet, 1963) and was found in the larvae and pupae of *Pieris brassicae* (Stamm and Aguirre, 1955) and of the silkworm (Watanabe, 1956a, and Tomino, 1963 and 1965). Dopa itself has been suggested as the chromogen in *P. rapae* (Goodwin, 1965) and is present in all stages of the silkworm (Watanabe, 1956a and b). Thus, the chromogens tyrosine and dopa seem to be present at all times. Furthermore, according to Buck (1953), "There is reason to believe that enzyme, substrate, and adequate oxygen are present together in the blood for some time prior to the actual formation of pigment. The puzzle, therefore,

is not so much in how melanin is formed, but in how its formation in the blood of the intact animal is prevented and its formation in cuticle so narrowly limited in time".

The well-documented necessity for oxygen in natural pigmentation was verified, and direct contact with the scales seems to be required, which is consistent with the low capacity of hemolymph to transport oxygen (Buck, 1953). However, Onslow's suggestion that pigmentation is triggered by air becoming available due to pulling away of the wing from the pupal case was discounted by removing a section of the pupal integument at the apical region and finding delays of up to 13 hours in air or 19 hours in oxygen before pigmentation commenced. An interesting example of oxygen supply as necessary but not sufficient to initiate pigmentation is given by Fraenkel (1935) for the newly eclosed blow-fly *Calliphora erythrocephala*. Pigmentation was inhibited and postponed by allowing the flies to dig for an abnormally long time through sawdust in the presence of air, showing that exposure to oxygen on emergence from the pupal case was not sufficient to cause chromogen to oxidize but that there is "certainly a nervous mechanism involved in initiation of the coloration process". This nervous mechanism might function through a shift in oxidation-reduction potential of the blood due to stress; see Buck, 1953.

In conclusion, the complexity of the living system, both structurally and chemically, makes dubious any simplistic mechanism that might be proposed to explain pigmentation. Some points can be demonstrated, but no general hypothesis, e.g. that of Braun (1939), is very convincing when alternate explanations can be suggested which also fit the limited data.

SUMMARY

Pupal wings of *Pieris rapae* (L.) were dissected and studied at various times from pupation to eclosion (9-10 days). Scales grew to full size from approximately 3 to 5 days with no apparent difference between the future-white and future-black varieties. At 5-6 days the wingcases became noticeably whitened. During the next 3 days, before the onset of black pigmentation, the presence of pterin pigments in the future-white scales, and their substantial absence in the future-black scales, was indicated by dark staining of the future-white scales with iodine solution followed by 50% sulfuric acid, selective reduction of ammoniacal silver nitrate by the future-white scales, and selec-

tive pink coloration of the future-white scales by the murexide test (chlorine treatment). Also, the future-black scales, lacking pigment, were relatively translucent. A "relief stage", as reported by W. Braun (1939) for species including *Papilio ajax* (L.), was seen on brief drying of the wing in air; the future-white scales appeared erect, the future-black scales collapsed. Artificial pigmentation, reported by Braun using saturated tyrosine solution, was more effectively achieved with dopa. Another successful chromogen was catechol. Before white pigmentation at 5-6 days, all scales darkened in 0.5% DL-dopa solution at the same rate, but in older pupae the future-black scales darkened faster and so were blackened selectively at short times, e.g. 2 hours, though the whole wing became very dark by 48 hours. This process is an enzymic oxidation requiring traces of oxygen and prevented by melanogenesis inhibitors such as thiourea or ascorbic acid or by brief heating of the wing at 90°C to destroy the oxidase. Premature pigmentation also was achieved by soaking the wing in pupal hemolymph, whereas darkening of the future-black scales in water was at best faint. Thus, the data indicate that the scales contain oxidase but are deficient in chromogen. The reason for the pronounced difference in rate of darkening in dopa solution between future-black and future-white scales was not clear. Alternative explanations include less oxidase in the future-white scales, greater permeability of the future-black scales, and inhibition of melanin formation in the future-white scales. The selective presence of pterin pigments in the future-white scales possibly might explain not only artificial pigmentation (pterins are known melanogenesis inhibitors) but also the "relief stage" by reinforcing effect of pigment deposited in the walls of the scale. The complexity of this biological system, and the variety of explanations fitting the limited data, make questionable the simplistic explanations that have been proposed for black pigmentation *in vivo*, of which artificial pigmentation is a pale and relatively nonselective simulation. Pigmentation *in vivo* is not triggered by exposure of the wing surface to air, as has been suggested (Onslow, 1916), because darkening commenced and proceeded normally at times of up to 19 hours after removal of pupal integument to expose the apex of the wing to water-saturated air or oxygen. This result, coupled with the observation of a delay in darkening vs. the untreated apex when the exposed apex was covered with petroleum jelly to exclude air, suggests that availability

of oxygen at the wing surface is necessary but not sufficient to initiate the rapid (about 5 hours at 80°F) formation of black pigment.

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TWO NEW FORMS OF PLEBEJINAE FROM WYOMING

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DURING THE 1969 COLLECTING SEASON, two heretofore undescribed forms of Plebejinae were taken. They are now briefly described.

Plebejus (Icaricia) acmon lutzi form nov. *pseudolupini*

This insect is being described from a series of ten males. In facies, the butterfly resembles *I. acmon lutzi* dos Passos with the exception of the submarginal orange spot-row on the secondaries. Both ventrally and dorsally this row is broken into discrete small spots resembling those on *lupini* (Boisduval). In several of the specimens, the spots on the upper side are almost obsolete. The black portion is clear, but the orange coloring is extremely reduced. Ventrally the orange spots are larger than those above, but are much reduced over normal *lutzi*. The male genitalia are identical to *lutzi*.

Holotype. — ♂, near Eagle Rock, 8200' approx., Sherman Range, Medicine Bow N.F., Albany Co., Wyoming, 27 June, 1969.

Paratypes. — 1 ♂, 27 June; 2 ♂, 29 June; 2 ♂, 1 July; 4 ♂, 6 July, 1969. The paratypes are from Pole Mountain, 8200' approx., Sherman Range, Medicine Bow National Forest, Albany Co., Wyoming. Expanse (costal margin length): 1.22 cm average.

Plebejus (Plebejus) saepiolus saepiolus

♀ form nov. *caerulescens*

The description is based upon a series of seven specimens from the type locality, which is in the Black Hills along the Weston Co., Wyoming — Lawrence Co., South Dakota boundary. The author has in his collection three additional females from Arizona (Apache Co., vic. Alpine, 8200'-8500') which resemble the form being described.

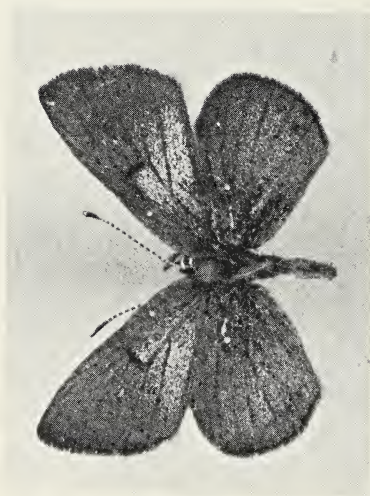


Fig. 1.—Top: dorsal and ventral views of holotype male of *Plebejus* (*Icaricia*) *acmon lutzi* f. *pseudolupini*; Bottom: dorsal view of holotype female of *Plebejus* (*Plebejus*) *saepiolus* f. *caeruleus*.

Two subspecies of *saepiolus* (Boisduval) are recorded from the Rocky Mountain region: *saepiolus* (Boisduval) and *whitmeri* Brown, although *gertschi* dos Passos may intrude into the western slope. "Normal" females of *saepiolus* are warm brown dorsally with a submarginal orange spot-band on the secondaries which varies from obsolete to relatively distinct. Occasionally the ruddy female form *rufescens* (Boisduval) is taken. *P. saepiolus whitmeri* females show extensive dorsal blue of the same hue as the males.

The new form represents a certain percentage of the female population of *s. saepiolus* in the Black Hills. It differs from normal females by having substantial dorsal blue scaling. On the primaries this extends from the body over the basal half of the wings; on the secondaries, the amount of blue varies in extent and ranges from the basal half to the entire wing surface. The dorsal submarginal orange spots on the secondaries may or may not be present, as in usual *saepiolus*. Dorsally the brown ground color is darker than in normal *saepiolus*, especially at the apex of the forewing. The blue color generally suggests a darker hue than that of the male and is quite luminous. It is a deeper shade of blue than is found in *whitmeri*.

Holotype. — ♀, Crooks Tower Road, Black Hills N. F., 6000' approx., Lawrence Co., South Dakota, 4 July, 1969.

Paratypes. — 3 ♀, same date and location as holotype; 1 ♀ 2 July, and 2 ♀ 4 July, 1969 from Weston Co., Wyoming — Lawrence Co., South Dakota boundary along U. S. Highway 85.

Expanse (length of costal margin): 1.38 cm average.

The author would like to acknowledge a discussion with F. Martin Brown which led to preparation of this paper. There has been no distribution of paratype material to date, as the specimens are needed for a continuing study of Wyoming Rhopalocera.

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CONCERNING THE NAMES AND STATUS OF CERTAIN NORTH AMERICAN MEMBERS OF THE GENUS PHYCIODES

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IN HIS "SYNONYMIC LIST OF THE NEARCTIC RHOPALOCERA," 1964, dos Passos lists *pulchella* Bdv. (556c, p. 82) as a subspecies of *tharos* Drury, with the more familiar *pascoensis* Wright as a synonym. If the name *pulchella* actually applied to a western entity, as Boisduval apparently believed it did, this listing would be the valid one.

However, a study of all available references has convinced me that the name *pulchella* cannot apply to any western population of *Phyciodes tharos*. The name *pulchella* first occurs (Boisduval, 1852) as follows (my translation from the original French):

49. *Melitaea pulchella*

Pap. Tharos. Drury. Ins. I. pl. 21. f. 5.6.

It occurs in a large part of California. This species should not be confused with *tharos* Cramer that also (equally) inhabits the United States. It is well to note also that *morpheus* Cramer, figured on plate 101, is identical in every respect with that which was previously figured under the name *tharos*.

Since this is an indication that the figures cited depict what Boisduval had in mind as *pulchella*, and since there is no other description, the insect from which the figures were made may be regarded as the type of *pulchella* Boisduval. Drury, in 1773, could scarcely have had material from California. Edwards (1864) states that Drury's specimens of *tharos*, on which his plates were based, came from New York. If this is true, no figures of these New York specimens can form the basis of the name of an entirely western population. It seems clear that Boisduval's name, *pulchella*, is a synonym of nominate *tharos* Drury, and cannot apply to the insect we have known as *pascoensis* Wright.

It is difficult to know what Boisduval had in mind when he proposed *pulchella*. No population of *tharos* is found over "a large part" of California. If *tharos* occurs in California, it is only in the northeastern corner of the state. The dark *Phyciodes* of California is *campestris* Behr (1863), at that time undescribed. It is possible that Boisduval confused *tharos* and *campestris*, but in no way did he suggest a name for what we now know as *campestris*. It seems unlikely that Boisduval had specimens of what he called *pulchella*, or he would not have needed to give that name to a figure.

In 1869 Boisduval (Ann. Soc. Ent. Belg. 12:20, no. 50) mentions *Melitaea pulchella* again:

50. *Melitaea pulchella*, Boisd.

Papilio *Tharos*, Drury, Ins. I. Pl. 21, f. 5-6.

Well scattered (assez répandue, or distributed) in central California. This species should not be confused with *Tharos* Cramer which inhabits certain parts of North America.

And again in 1869, Boisduval (ibid. 12:53, no. 37) writes of *Melitaea tharos* Boisd. et Leconte (!?), gives *Argynnis tharossa* Godt., as a synonym, and again says of *tharos* that it "occurs also in certain localities in California."

And finally, in the same work, next number (no. 38) he lists *Melitaea cocyta* Cramer (now considered a synonym of *tharos*) with *Argynnis morpheia* Godt. as a synonym. Of *morphea* he says, "It was captured at Los Angeles."

These references indicate that Boisduval persisted in thinking (a) that *pulchella* was different than *tharos*, and (b) that both *tharos* and *pulchella* occurred in California.

It is interesting to note that neither of the common lowland California species of *Phyciodes* (*mylitta* and *campestris*) were among the material sent to Boisduval by Lorquin and described by Boisduval in 1852. This strengthens the inference that the earlier Lorquin collections were made in the mining country of the Sierra Nevada, rather than in the Bay Region of California. It is suggested that caution be used in fixing San Francisco as the type locality of species described by Boisduval in 1852.

In his Synonymic List (1964) dos Passos listed *mata* Reakirt as a subspecies of *mylitta* Edwards, with *barnesi* Skinner as a synonym, but more recently (Journ. Lepid. Soc., 23:120) he places *mata* as an aberration of *P. campestris camillus* Edwards (569b). The checkered history of this name, given to a very unusual appearing single specimen, is interesting. Reakirt described it as a bleached specimen which nevertheless he considered to represent a distinct species (Reakirt, 1866). Strecker, (1874) says of this type of *mata*, "Female. Expands 1½ inches."

Brown (1966) devotes an illuminating paragraph to the *mata-pallida* problem. He considers the type of *mata* to be albinic rather than faded (an opinion expressed earlier, by Strecker). Brown states, "if it is *mylitta*, it is unusually small." From this I judge that Strecker's measurement of "1½ inches" is very approximate, since this is very *large* for a *mylitta*.

Brown (loc. cit.) finds it impossible to decide whether *mata* belongs to the concept of *mylitta*, or to *camillus*. This seems to have been the reaction of all who have discussed this specimen. Reakirt thought it faded; Strecker and Brown thought it not faded; Barnes & McDunnough (1916) thought it to be *mylitta*, both worn and faded when taken. None seems to agree. The recent action by dos Passos disposes of the name as populational. This seems far better than to use the name *mata* to affect other better established names.

Concerning the status of the names *pallida* Edwards and *barnesi* Skinner, which have traditionally been associated with *mylitta* Edwards, there is what appears to be good biological and distributional evidence that *mylitta* and *pallida* are distinct species, with *barnesi* a weakly differentiated subspecies of *pallida*. Here is the evidence: *pallida* and *barnesi* are one-brooded. *Mylitta* is holodynamic wherever found, breeding continuously as long as weather conditions permit. In Utah and northwest into Washington, both one-brooded populations (*pallida-barnesi*) and multi-brooded populations (*mylitta*) are sympatric and separable when once known by subtle markings as well as by size. The *pallida-barnesi* complex are consistently larger insects, and have a dark spot in cell Cu₂ of the forewings that shows on both upper and lower surfaces, in most specimens. In addition, the females of *pallida-barnesi* show a more or less complete row of outer crescents on the underside of the hind wings, these crescents creamy or buffy, and no one of them much darker than the others.

P. mylitta averages smaller, is multi-brooded over its entire range, lacks the dark Cu₂ spot in most specimens and the females, as in the males, have one of the crescents on the underside much darker than the others, the typical "crescent spot." Populations of *pallida-barnesi* and of *mylitta*, when sympatric, are not synchronic. The single brood of the *pallida* complex peaks at a different time than any of the several broods of *mylitta*.

These pieces of evidence convince me that *mylitta* Edwards 1861 should be considered one species, and that *pallida* Edwards 1864 should be regarded as a separate species, with *barnesi* Skinner 1897 as a western subspecies of *pallida*.

The type locality of *pallida* Edwards was fixed by Brown (1966) as Flagstaff Mountain, Boulder Co., Colorado. The stated type locality of *barnesi* Skinner is Glenwood Springs, Garfield Co., Colorado, far west of the Continental Divide and climatically allied to Utah. *P. pallida barnesi* extends south from the type locality to northern Arizona and northwesterly to Washington and southern British Columbia, east of the Cascades. Over much of this range it occurs with *mylitta*. I have examined sympatric material of these species. Lack of similar material from the higher eastern parts of Colorado suggests that true *mylitta* either does not extend there, or is rare there, or that the distinctions between *mylitta* and *pallida* may have been overlooked. I favor the first hypothesis. Plentiful material that I have examined from eastern Colorado seem to me to be all *pallida*. Genitalic distinctions are either minor or nearly lacking between these two species but may be demonstrated by further studies.

Changes in the listings of our *Phyciodes* have been frequent but the following seem justified:

566. *tharos* (Drury) 1773

a. *t. tharos* (Drury) 1773

pulchella (Boisduval) 1852

(return to former synonymy)

b. *t. arctica* dos Passos 1935

c. *t. pascoensis* Wright 1905

and: 571.1 *pallida* (Edwards) 1864

a. *p. pallida* (Edwards) 1884

b. *p. barnesi* Skinner 1897

572. *mylitta* (Edwards) 1861

The status of any populations that may belong under *mylitta* does not form a part of this paper, but will be treated separately by Mr. David Bauer.

I am grateful to Mr. David Bauer for critical review of the manuscript and for many valuable suggestions. He has been kind enough to allow me to read the manuscript of a forthcoming paper in which he expresses the same conclusion regarding the specific status of *Phyciodes pallida* (Edwards).

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THE LIFE HISTORY OF AMBLYSCHIRTES LINDA (HESPERIIDAE)¹

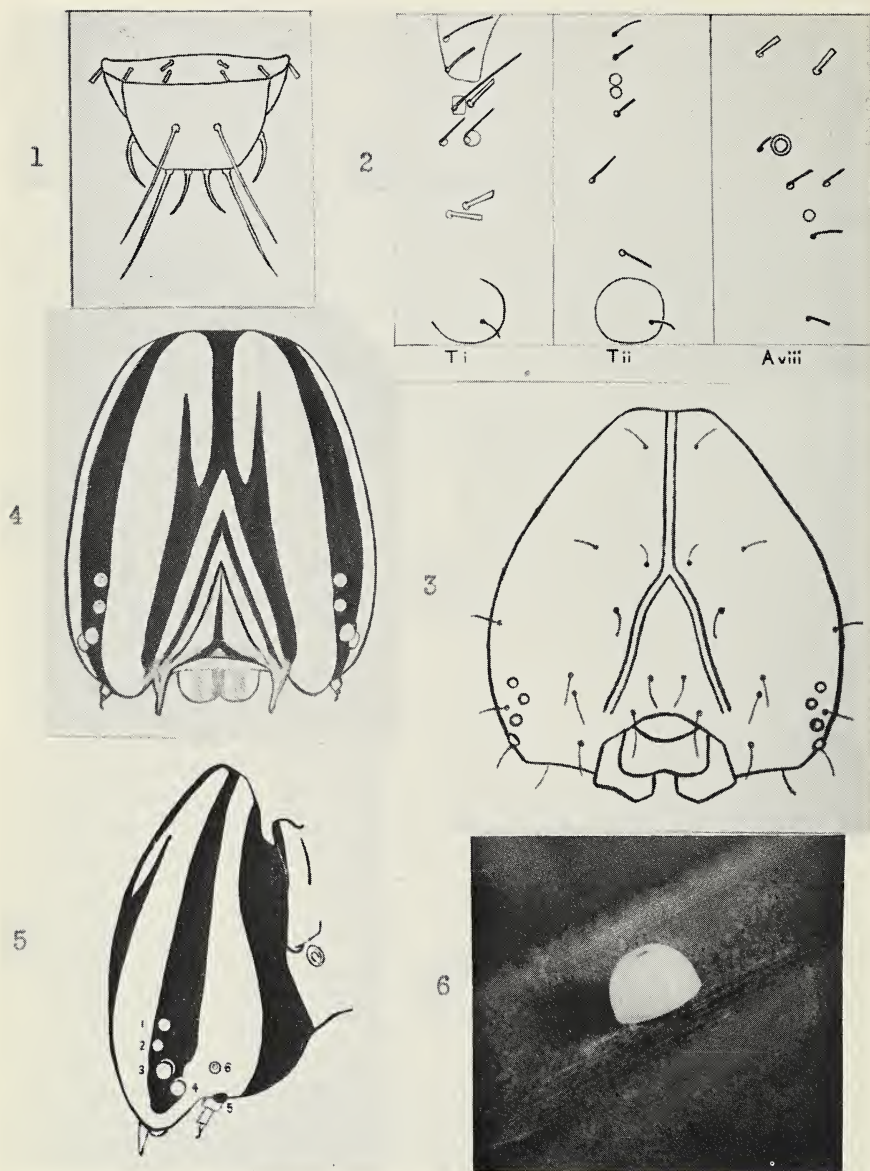
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Five forest dwelling species of *Amblyscirtes* are known to occur in the Missouri-Arkansas plateau region. Of the five, *Amblyscirtes linda* H. A. Freeman is the most eremitical. We have found this species a habitue of undisturbed woodland areas along or near small streams with abundant colonies of the host plant. Although the foodplant, *Uniola latifolia* Michx., occurs in most of the Midwestern and Eastern states, the northern range of *A. linda* seems to be the southern tier of counties in Missouri. The Gramineae host species is one of the favorite lepidoptera foodplants of the region acting as primary or secondary host for *Amblyscirtes belli* H. A. Freeman, *Amblyscirtes samoset* Scudder, *Amblyscirtes vialis* Edwards, and *Lethe anthedon* Clark. *A. linda* females can occasionally be collected from low blooming flowers of the wild blackberry and are easily induced to oviposit in captivity. The progeny of early May females have invariably developed rapidly with a 100% emergence of the imagines in June. We have never encountered a third brood in the field and if one occurs it is probably vestigial as with *A. belli*. The adult larvae are unique in several aspects from the other members of the genus that we have studied. The freshly emerged imago is distinctive with bright fulvous scaling on the dorsal and ventral surfaces of the forewing. Worn specimens lose this fulvous scaling and are then easily confused with *A. vialis* and *A. belli*.

The following description is based on studies of over 100 reared and field collected larvae from northern Arkansas and southern Missouri localities. The illustrations were made by the junior author from specimens reared from a female taken 3 May, 1964 near Eureka Springs, Arkansas.

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Figs. 1-6.—*Amblyscirtes linda* H. A. Freeman. 1, setae of first instar suranal plate; 2, first instar setal maps of prothorax, mesothorax, eighth abdominal segment, all in left lateral aspect; 3, first instar head capsule, frontal aspect; 4-5, mature larva head capsule, frontal and left lateral aspect showing position of stemmata; 6, ovum X 25.

OVUM: Width .90 mm, Height .65 mm, As pictured, unmarked shiny white in color. Ova are laid singly on the under surface of a leaf near the edge. The egg shell is devoured upon emergence.

FIRST INSTAR LARVA: Head and prothoracic shield shiny black. Integument white with minute white setae. After devouring the egg shell the larva moves to the edge of a leaf and makes a small tent shelter by folding the edge of the leaf partially over and fastening it with strong silken strands.

SECOND INSTAR LARVA: Head and prothoracic shield shiny black. Body color pale bluish green covered with minute white setae. There is a faint indication of a middorsal line. Larval tent as in first instar but longer, in some cases as much as 30 mm. in length.

THIRD INSTAR LARVA: Head white with dark brown lines circling the edges of the epicranial plates and covering the posterior region of the head. Labrum and mandibles brown, clypeus white. Body color pale bluish white with a thick covering of microscopic white setae. Prothorax paler with a contrastingly shiny black prothoracic shield. Thoracic spiracle black, abdominal spiracles inconspicuous. There is a pale blue middorsal heart line fading posteriorly. An entire leaf is used for the tent in this instar which is folded in half and sealed along the edges. The tent is then devoured from the tip down.

FOURTH INSTAR LARVA: Head white, mandibles and labrum reddish brown, clypeus white with a fine black center line. Midcranial inflection black edged, wider along the laterofacial suture. A dorsally directed black dash extends parallel to the wide central band on each side rising from the laterofacial suture band and stopping a few millimeters short of the vertex. Posterior region of head black ringed. Another wide black band circles the edges of the head beginning ventrally just below the anterior stemmata then rising dorsad to the vertex, narrowing where intersected by the midcranial inflection. Head finely setose. Body ground color bluish white, entirely covered dorsally by very short white setae. The posterior end of the abdomen has longer pure white setae. There is a blue middorsal line fading posteriorly and a faint white stigmatal line. Thoracic spiracle black, abdominal spiracles small, white ringed. Abdominal area pale bluish grey. Prothorax pure white with a thin black prothoracic shield. Larval tent as in the third instar.

FIFTH INSTAR LARVA: Length of mature larvae 25 to 30 mm. Width of head case 3.5 mm. Body ground color pale bluish white so thickly covered with snow white setae that the entire body appears covered with snowy mold. There is a faint blue

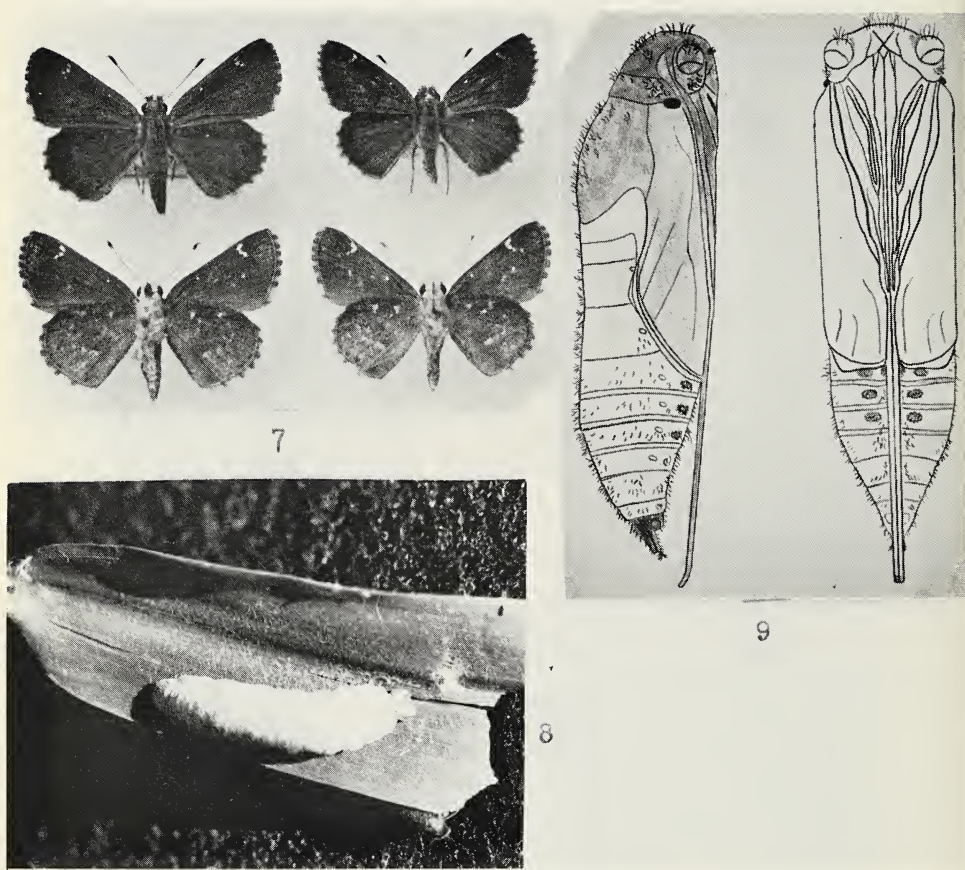


Fig. 7-9.—*Amblyscirtes linda* H. A. Freeman. 7, adult male and female, ventral and dorsal view of specimens from Eureka Springs, Arkansas; 8, mature larva in opened larval tent, natural size; 9, pupa, ventral and right lateral aspect X 4.

middorsal line that disappears posteriorly. Abdominal area slightly bluer with fewer, shorter setae, Spiracles as in fourth instar. Thoracic legs very pale orange brown. Prothorax white with prothoracic shield pale grayish white with two narrow dark subdorsal marks. Head white, mandibles reddish brown, clypeus white with vertical line and lateral bordering sclerites black. Head banded on each side with a wide black line, ventrally enclosing the four anterior stemmata then running dorsad across vertex where it narrows. Midcranial inflection widely banded with black as are the laterofacial sutures. A pointed black band rises from each of the laterofacial suture bands. The paraclypeal spines (Klots 1966) are well developed, arising from a position ventro-lateral to the angle of the clypeus and angled ventrad. Of the four anterior stemmata, 3 is the largest, 4 slightly smaller, 2 is slightly smaller than 1 but protrudes twice as far, 6 is almost directly caudad of 3, 5 is ventrad of 6. At maturity the head markings are partially obliterated by an extremely thick covering of short white setae.

The final instar larval tent is composed of an entire leaf folded over and sealed along the edges with silken strands. Both upper and lower ends are left open. Adjacent leaves as well as the tent leaf are entirely devoured. Larvae are often observed feeding openly in the daytime, especially in native woodland habitats. The larvae are unusually docile, showing no agitation when touched or handled.

PUPAL SHELTER: When the larva is ready to pupate a fresh leaf is rolled over and sealed along the edge and both ends. The larva spins only a vestigial silk lining. The tent is fastened at the upper end to a grass stem two or three inches above the ground. No instances of the shelters being allowed to fall to the ground have been observed although this has been the accepted practice with other *Amblyscirtes* species we have reared. Pupation occurs three to four days after shelter construction.

PUPA: Length 17-19 mm., width at wing cases 4.5 mm. Color of wing cases bright creamy yellow, abdomen paler with a whitish cast. Head and eye cases slightly darker with many stiff reddish setae, a few of which extend over onto the thorax. Mesothoracic spiracles bright red and conspicuous. The abdominal segments have a sparse covering of short orange-red setae arranged in definite tufts on each segment paralleling the tounge case which is pale orange brown, long, and slightly curved. Cremaster reddish brown, curved ventrally with several long stiff bristles. The cremaster hooks are firmly embedded in the

side of the shelter and hold the pupa in fixed position at the base of the tent.

Our special thanks are due Dr. Alexander B. Klots, American Museum of Natural History, and Dr. Howard V. Weems Jr., Florida State Department of Agriculture, for reading the manuscript and making helpful suggestions.

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FURTHER OBSERVATIONS ON "HILLTOPPING" IN *PAPILIO ZELICAON*

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IN THE PAST I HAVE WRITTEN two papers in which I set forth the "mating rendezvous" theory to account for the hilltopping habits of certain butterflies. During the ensuing years many things have come to my notice that have sapped my confidence in this theory. After coming to live on Thetis Island in 1965, I found myself in an excellent position to study the habits of *Papilio zelicaon*, which is by far the most notable and persistent hilltopper. The results of my observations here have caused me to abandon the mating rendezvous theory entirely.

Later, in correspondence with Mr. Oakley Shields of San Diego, California, I learned that he was making a detailed study of *P. zelicaon*, with a view to publishing a paper on the hilltopping habits of this species. I felt that, owing to my limited opportunities for research, I could do better by collaborating with Shields, rather than writing up my own findings. He accepted my suggestions for this plan, and for over a year I sent him several long letters detailing my observations. In his paper, "Hilltopping" (196), he referred the reader to my published papers which I had repudiated.

I conceived the idea of crudely marking, and releasing, a few male *P. zelicaon*. I first considered this as a preliminary test, intended mainly to show whether the recovery ratio would be sufficient to warrant a more elaborate program. However, I now feel that the results achieved are worthy of publication.

Thetis Island consists of two ridges running approximately north and south, each about 4 or 5 miles long and reaching 600' at the highest point. Between these ridges the valley is for a large part below, or barely above, high tide level. In the southern part of this valley an area of about 10 acres is almost flat,

supporting a rank growth of swamp loving herbage, mainly sedges (*Carex* spp.) with a considerable admixture of the water parsley (*Oenanthe sarmentosa*). Undoubtedly, in this swamp most of the *P. zelicaon* population of island feed as larvae.

The land rises quite evenly from the swamp to the summit of the west ridge (Birchall Hill). This hill is close to, and easily seen from, the swamp, and so should provide the most likely place to find hilltopping butterflies. In fact, it is heavily wooded and I have never seen any butterflies there. From the east side of the swamp rises a sheer cliff 100' high, blocking off all view of the east ridge (Moore Hill). Between this cliff and Moore Hill the land is irregular with many small ridges and valleys. It seems improbable that any insect could find the hill by following land contours, as suggested in my paper on *Oeneis*. Moore Hill is very sparsely wooded at the extreme summit, and on the gradual slope extending northward. It is much frequented by butterflies, chiefly *Papilio zelicaon*, *P. rutulus*, and *P. eurymedon*.

My system was to clip off the tip of one forewing of butterflies to be released. Those collected on Moore Hill had the left wing clipped, those collected in the swamp the right wing. As an additional check, I clipped the tail from the hind wing opposite to the clipped forewing. Due to the frequency with which *Papilios* lose the tails by accident, I did not plan to draw any conclusions from insects with missing tails, unless this mark was clearly supported by a clipped forewing. In any event I caught only one individual which had lost the tip of a forewing, other than those which were clearly my released specimens. This one had part of a wing removed leaving a ragged edge, not neatly clipped as in my marked specimens. Both tails were intact. All others, counted as recaptures in the ensuing account, had neatly clipped forewings, and the opposite tail only missing.

In addition to my marking and releasing program, I kept records to ascertain the average time needed to collect, respectively, a male and a female *P. zelicaon*, on the hilltop and in the swamp. I also tried to estimate the number of *P. zelicaon* usually present on the hilltop; as there were very few, this was not difficult. Due to the large area and the large number of butterflies present, no estimate that would be of any value could be made of *P. zelicaon* numbers in the swamp. On the hill I noted, each day that I collected there, (a) the largest number of *P. zelicaon* seen together at one time, and (b) the minimum number

that could have visited the area during my stay. The last figure was arrived at by adding to the number collected any others seen after I had ceased collecting.

The areas which I collect at a given time are decided mainly by mercenary considerations. When *P. rutulus* and *P. eurymedon* are present I collect the hill; when only *P. zelicaon* are available I collect the swamp. As *P. zelicaon* is by a week or two the earliest on the wing of the three species, I commence the season by collecting the swamp, but soon resort to the hill until all species become too worn to be worth any further effort. When the late brood of *P. zelicaon* emerges, the other two species being single brooded, I collect the swamp for the remainder of the season. Thus I did not manage to check the swamp for the possible return there of specimens taken on the hill.

All releases were carried out in my garden. Unfortunately, I do not have any map of a scale that would allow of my calculating exactly the distances involved. The distance to the swamp is a little over a mile; the distance to the hilltop several times farther, a circumstance which can hardly account for the results as follows. The first *P. zelicaon* of the season I collected in the swamp on May 8; these were 2 females, not absolutely fresh. From that date up to May 18, I alternated between the hill and the swamp. The first release from the swamp I made on May 17, but as I did not return to the swamp until June 5, later disclosures will show that I had little opportunity to recapture this one. On June 5, I released two from the swamp, but returned there only one more day, June 7. On that day, I released three from the swamp.

From May 14 to May 25, I was at the hill on alternate days. I released one butterfly on each of the following days: May 16, 18, and 21. On May 25, I released two. On May 18, I recaptured a marked specimen in my garden. I had not yet made that day's release, so this specimen was the one released two days earlier; it had made no attempt to travel anywhere. Following the May 25 releases, I did not get back to the hill for five days. I was then at the hill May 30, June 2, 4, 8, 10, 11, and 13. I released one specimen June 2 and one June 8. On June 10, I recovered one specimen which had been marked and released from the hill; this was the only one retaken while collecting on the hill. I took this one home again, clipped the other wing, and released it; on the two subsequent days I returned to the hill I did not see it. Early flight *P. zelicaon* were now mostly

worn, so I terminated my spring collecting on the hill.

On July 13 I noted second brood *P. zelicaon* on the wing and therefore tried the swamp again. On that day I released four butterflies. I did not get back to the swamp again until July 16, when I recovered one of the July 13 releases. I took this one home, clipped the other wing and released it again, together with the three others captured on the same day (July 16). On my next visit to the swamp, July 18, I recovered two once marked specimens. Both of these, I double marked and released again. On my next and last visit to the swamp, July 21, I recovered one twice marked specimen. On that day, I also recaptured a twice marked specimen at my garden.

In summing up, I think I may be permitted to ignore the six spring brood specimens from the swamp which I released. I made almost no effort to recover these; at that time I supposed that if I did see them again it would be on the hill. Thus we have a recovery rate of one out of seven released from the hill, this one being double marked and not seen again. From the swamp, we have a recovery of three out of seven, these three being double marked and one of them recovered again. In view of the small number of butterflies used, and the much greater distance from the release point to the hill, I can hardly claim that these figures offer convincing evidence to the effect that the butterflies returned more readily to the swamp than to the hill. Still, I think that they can be regarded as suggestive. In any case, this is irrelevant to the theory that I set out to gain evidence on, namely, that butterflies from the swamp had no interest in the hill. I had as much opportunity of recovering the six early releases from the swamp, had they gone to the hill, as I had of recovering the seven released in the summer.

My data for collecting success are also interesting. They show that in the swamp I required 15 minutes to collect a male, and 50 minutes to collect a female. On the hill I required 28 minutes to collect a male, and 5 hours 45 minutes to collect a female. Actually these figures are highly misleading in favor of the hill. On the hill the butterflies are concentrated into about half an acre of level or moderately undulating ground, with a few scattered trees. and only very short grass or mosses between them. The butterflies pass repeatedly over a largely predictable course and so are easily intercepted. In the swamp they are scattered over 10 acres, mostly covered with knee-high saw-edged sedges. This area was at one time cultivated as a market garden, and to keep it drained, it was crisscrossed with

a system of ditches up to two feet deep. Through many years of neglect these ditches have ceased to provide drainage, but many are still effective as traps for unwary butterfly collectors. There is no hope of running through this mess, and no sure way of predicting the course that any butterfly will take, in order to intercept it. Of course, there is no basis on which I can estimate accurately the effect of these handicaps on my collecting success, but as a guess I should say that the opportunity of securing any particular butterfly is ten times as great on the hill. From my records I find that in fact I never saw more than two *P. zelicaon* together on the hill, and it is possible that no more than six in all were there during any of my visits lasting from one to three hours.

It will be realized that to make this collecting at all profitable, I was taking mostly other species, and so it may be supposed that my poor success with *P. zelicaon* was due to such distractions. Actually, since *P. zelicaon* are much easier to net than *P. eurymedon*, and much more in demand among collectors than *P. rutulus*, I always concentrate on any *P. zelicaon* that show up, going for the others when no *P. zelicaon* are in sight. Again, after my elaboration of the difficulties of collecting in the swamp, it may be wondered how I was able to recover so many marked specimens from among the large number scattered over the area. I think the explanation here is that the insects returned, not just to the swamp, but to a particular small area that they had staked out as territory. They may travel over a considerable distance, but as a sort of patrol, continually passing and repassing over the same track. There are in the swamp some patches of slightly higher ground that are dry, and lack the heavy cover of sedges. I soon learned that I attained as much success by staying on these dry patches and trying to intercept any passing insects, as by running all through the sedges and falling into the ditches. It can be seen that if a butterfly returned to its regular patrol, I would collect it again.

There is one evident conclusion to be drawn from these observations. The hilltop is not a permanent attraction for a large part of the *P. zelicaon* population. It is just a good collecting place because it is a very small area in which the presence of a few butterflies can be reliably predicted. When, as is the case here with *P. eurymedon* and *P. rutulus*, the host plants are scattered thinly over a wide area, the hill may be the most productive collecting site. But when, as with *P. zelicaon* here, a large proportion of the available host plants are con-

centrated into a relatively small area, this emergence area provides, on the whole, a better collecting site than does the hill.

The small number of males on the hill could be explained by postulating that these are dominant or successful individuals, which drive all others off. But it is not so easy to account for the almost complete absence of females. In fact, there is no evidence that the hill has any attraction at all for females. I am sure that if I were to mark out half an acre of grassy land anywhere on Thetis Island, and spent five hours there, during the flight season of *P. zelicaon* and while temperatures were favorable to butterfly activity, I could not fail to collect one or more females. In my garden, where there are a fair number of flowers attractive to butterflies, I would quite certainly do much better than that.

When expounding the mating rendezvous theory in my *Oeneis nevadensis* paper, I supposed, with some justification, that *O. nevadensis* was a rather rare insect in the area of my observations. This, added to the fact that females would leave the hilltop immediately after copulation was ended, nicely accounted for my seldom collecting any there. But for a species as common as *P. zelicaon* is on Thetis Island, this theory will not do at all. Every female would have to make at least one visit to the hilltop. Shields, in a letter, has suggested that I do not collect the hill at the right time of day. I have frequently been there in the morning when butterflies were barely starting to move. On the British Columbia coast, where spring nights are always cool, this does not by any means require early rising. There remains the late afternoon. But it is obviously impossible for the insects to predict their time of arrival at the hilltop. One cannot imagine a whole flock of females hiding just down the slope somewhere, waiting to pop up at a given signal. If the collector remains on the spot until mid-afternoon, as I have often done, and no females have shown up, it is safe to predict that there will be very few there that day.

My mating rendezvous theory as set forth in my earlier essays depended on the proposition that the butterflies concerned emerged from the pupae as a few individuals widely scattered. To *P. zelicaon* on Thetis Island, this cannot apply. Plenty of both sexes can be seen at the swamp, and it is quite evident that none of them are headed anywhere in particular. The females are ovipositing and the males are looking for females. I have observed many courtship flights, but seen few actually in copulation. My failure to observe actual pairs may

be largely due to the fact that I would sooner collect the insects than wait to see what they are going to do. But it is probable that most butterfly courtships end abortively simply because females are receptive only for short periods. Whatever the reason for the scarcity of copulating pairs, it obviously cannot be because the females are staving off their suitors until they can get to the hilltop. The advantage accruing to those that "cheated" would be tremendous. They would avoid waste of time and effort entailed in a long hazardous return journey. Shields' idea that there is an advantage in stabilizing the gene pool is not very convincing. This makes it one of those cases where a habit not beneficial to the individual becomes established because it is of benefit to the population as a whole. I do not wish to wander off here into a long discussion of this concept. It must suffice to say that such a habit must be neutral or at the worst only slightly detrimental in its effect on the individual, otherwise it could not persist long enough to become established in the population.

It would be foolish, of course, to claim that Shields' experiment proved nothing at all. The fact that his butterflies sometimes returned to hills other than those from which they were taken, shows that the homing instinct is not entirely responsible for his recovery of marked specimens. His theory of hilltopping by direct view of the hill is far better than my idea of insects following the ground contours, as set forth in my *Oeneis* paper. But it forces the conclusion that insects cannot reach a hilltop until they come by accident to a point from which they can see it. It could hardly be of much benefit to males to spend their time waiting on a hilltop for females, a large proportion of which would never get there. Shields, as his illustration plainly shows, was able to work on neat little humps sticking out of a nearly level and largely treeless plain. He would almost certainly have obtained different results if he had met with such a situation as pertains here, where very few summits can be seen before you are almost up to them, unless from certain points of vantage. A reasonable supposition would be that the hilltopping instinct becomes dulled under the latter conditions. But could this circumstance almost entirely eradicate an instinct which was of any great advantage to the possessors?

There is a definite relationship between the number of *P. zelicaon* commonly on a given hilltop, and the availability of food plants. On the hill at Wellington, which was much used by *P. rutulus*, *P. eurymedon*, and *Oeneis nevadensis*, I saw no

more than a dozen *P. zelicaon* in nearly 20 years that I collected there. Yet they were not entirely absent from the surrounding country, and I often found a few larvae on parsley in my garden. Mt. Benson, a very conspicuous lone summit, on most of my visits showed only two or three *P. zelicaon* at the summit. But on Mt. Prevost, which offers similar attractions, there are seldom less than fifteen or twenty. It is true that I have not discovered the source of this comparatively large population of *P. zelicaon* on Mt. Prevost. They could be feeding on *Lomatium*, which occurs plentifully near the summit. In my former paper on hilltopping *P. zelicaon*, I gave as my opinion that the *P. zelicaon* population on Mt. Arrowsmith were feeding on *Lomatium*. But I later came across a hollow near the summit which supported a good stand of *Heracleum lanatum*, a favorite host of *P. zelicaon*. Still, *Lomatium* remains a likely host, and the availability of food plants the most likely theory to account for the variable numbers of butterflies on different hills.

Shields made no attempt whatever to learn whether his virgin females could reach the summit if posed any problems in finding it. He did not quite release them on the summit but he might as well have. Certainly the non-recovery of the mated females is surprising and must prove something. But it does not prove that the virgin females went to the summit in order to find mates, although that would be a reasonable assumption, if there were not so much evidence against it. My guess is that if these reared females had been released out of sight of any hilltop, the virgins would have been recovered close at hand. The mated females, of course, have a strong urge to search for a suitable host plant, and this would account for their moving quickly away from the scene of their release.

If butterflies commonly attempted to reach hilltops from any distance, one would expect while collecting to note among all butterflies a cross country movement in a particular direction. Instead, nearly all of them tend to fly low, and, if they do not stay in the same place, they travel in such directions as will not force them to fly over or through trees. This is very noticeable when collecting on roads, when it is very easy to intercept one's quarry, or follow it for long distances, because of its reluctance to leave the nice clear track.

In the swamp here, female *P. zelicaon* are usually seen traveling slowly, with a rather hovering flight, just above the herbage, frequently dropping out of sight therein. Males patrol, also just above the herbage, evidently on the lookout for females. Since this quest often brings them down into the sedges, both

sexes exhibit a characteristic damage to their wings, consisting of numerous small cuts and nicks inflicted by the saw edges of the sedges. The reader will have remarked that I collected the summer flight for only about a week. The reason is that these sedge inflicted abrasions become so prevalent after a short time that the butterflies are not worth collecting any longer. On the hill, this type of damage did not show up at all, and I was able to take saleable specimens for over a month. This again provides evidence that the small numbers of *P. zelicaon* on the hill, in contrast to those in the swamp, are almost certainly due to the fact that no butterflies from the swamp ever get so far. Somewhere close to the hill there must be small patches of a suitable host plant, not associated with sedges.

There is a vast difference between my experience with *Rhopolocera* in general, and those of Shields and others, who list a large proportion of available species as hilltoppers. Part of this discrepancy, as I have already suggested, may be due to differences in the general aspect of the terrain. But I still find it very difficult to accept the idea of possible hilltopping, under any circumstances, of many species. Among the *Lycaenidae*, for instance, there are many species that I never see more than 50 yards away from a good stand of the appropriate host plant.

Mt. Benson offers a particularly good opportunity for assessing the hilltopping proclivities of butterflies. I have visited this summit an estimated 60 times during the past 24 years. On each visit I walk about four miles from an elevation of about 2000' to the summit at 3300'. On this hike, I have collected 30 species of butterflies, of which one, *P. zelicaon*, is almost always taken at the summit only, and two others, *Vanessa cardui* and *V. atalanta*, tend to be at the summit more often than elsewhere. The other 27 species are definitely not more numerous at the summit, and in many instances are less so. I have not included *Papilio rutulus* and *P. eurymedon* in my count of species, although I have taken both species infrequently in the first part of the climb. To have included them would have given the impression that I do not consider them to be hilltoppers, which they most definitely are. Their absence from Mt. Benson summit seems to be due to the fact that they have a strictly limited altitudinal range. It is interesting to note that this aversion to going beyond a certain height (about 2500' on Vancouver Island) completely inhibits their hilltopping instinct.

One of the commonest butterflies on Mt. Benson is *Oeneis nevadensis*. Females are not commonly seen at the summit.

Males are as plentiful on every little hump of rock or subsidiary peak, as at the summit. This circumstance does not support either the theory of Shields (and others) to the effect that the butterflies head for a conspicuous object on the horizon, or my theory of insects following ground contours. It seems much more probable, with *O. nevadensis* at any rate, that the butterflies have never been so far away from these sites selected as territories that they cannot easily blunder on them by chance. On my hill at Wellington, the illusion of hilltopping was imparted because there were no acceptable rock humps except at the top. Lately I have come across *O. nevadensis* males using as territories patches of bare sandstone showing no eminence above the plain. Evidently the exposed rock has a considerable influence on their choice. In the only occasion on which I have been able to observe an unconfined female *O. nevadensis* ovipositing, the act took place right on the summit of the Wellington hill, again supporting my theory that the insects do not go far to find their territories.

Several males may occupy the same territory. The very sparse population of *O. nevadensis* on my Wellington hill made it easy to suppose that only one male could remain on a site. Actually, when an insect has kept a territory to itself for a short time, any other male arriving will be accosted and perhaps driven off. But the principle, now well known to zoologists, that a stimulus applied too often over a short time, will produce a progressively weakening reaction, applies in this case. When several males are continually invading a territory, they become accustomed to one another. They then accost each other only briefly, and do not fight. This rule applies to other territory holding butterflies, including the *Papilio* species.

Limenitis lorquini provides another good example of a territory-holding species. But the reasons governing this butterfly's choice of sites are not nearly so evident as is the case with others that I have dealt with. After observing a number I have noticed a similarity. Most consist of a bare or grassy patch on a south facing slope, with dense shrubbery or trees at the upper end. The butterflies settle frequently on these shrubs or trees at varying heights from the ground. It is evident that a warm air current will travel up the slope to be intercepted by the trees at the top. I must make it clear that I am not claiming that most specimens of *L. lorquini* are found in these situations. Large numbers are found in what may be makeshift territories, or may not be territories at all, or the butterflies may be visiting

water, or wet spots to obtain moisture. But when a certain spot is consistently used by *L. lorquini* males, when it is always re-occupied shortly after being cleared off by the collector, then such a spot will usually fit the above description.

In recent years, the territory holding-habit has come in for much attention, and it has been shown that it exists in some degree in a very large proportion of animal species. Many experiments with different animals have shown that they possess an uncanny ability to return to their home territory, even over a completely unfamiliar course. But it has been shown that this ability is not inborn, nor is it necessarily its natal area which the animal knows as home. An awareness of the territory to be known as home must become imprinted on the animal, and this process may take a certain amount of time.

Among animals, winged insects must be particularly likely to be carried against their will by wind; moreover, their eyes are not fitted for making out fine detail. It is reasonable to suppose that insects may have some difficulty in remaining on any selected spot long enough to become familiar with it, so as to be able to return from a distance should such a necessity arise. Conspicuous features of the terrain, such as a hilltop, would help a lot in obviating this difficulty. Add to this the advantages of the heat holding qualities of rocks, warm updrafts, and exposure to the sun early in the day, and I think we have a fairly good theory to account for the selecting as territories of sites possessing the several features described above. But I still remain convinced that the main factor influencing the selection of a territory is its proximity to the spot where the insect commenced its adult life.

By accepting the idea that insects make no great effort to find a hilltop, but merely use one as a territory if they happen to blunder on to it, or see it, the objections outlined above are avoided; in contradistinction we need not suppose that hilltopping can become a blind instinct spread through the population by natural selection. This would account for some insects using hilltops which do not appear to offer many favorable features.

Over unusually favorable terrain, such as that so well depicted in Shields' illustration, insects might go to a hill by sight from quite a distance. Shields mentions particularly a marked butterfly which reached a hilltop concealed from the release point by a ridge. But to accomplish this feat the insect required nine days. Surely, in wandering at random for that length of time,

it is not surprising that it got into a position from which it could see the hill.

The study of congregations of insects, with a view to proving that a mating rendezvous is involved, could easily be approached with too single-minded an attitude. When the primary reason for the congregation is obvious, as when certain species of beetles appear in great numbers on a fallen tree, we do not express any surprise on noting the large number of pairs in copulation. We know that, in order to reproduce, these beetles must find a tree of their correct host species in a condition that makes it vulnerable to their attack. We do not dwell on the fact that the male beetles can have no interest in the tree itself, or we may suppose that it is emanations from the female beetles, rather than the tree, which attracts the males. The last may be the true explanation but that does not alter the fact that a knowledge of the beetles' life history is necessary in order to evaluate the true reason for the congregation.

To sum up, I consider that hilltopping is usually an aspect of territorial behavior. With many insects, hilltops provide a preferred site for territories, and will be used for that purpose when they can easily be reached from the point where the insect commences its adult life. When a number of individuals of a single species reach the same hilltop, they can manage by splitting it up into small territories, or by sharing a territory. Explanations to account for territorial behavior can be a very involved subject. Shields, citing various authors, mentions: (1) decreased chances of mass predation by a few predators, (2) less time spent in intraspecific aggression, (3) increased frequency of male-female encounters, and (4) decreased interference to courting and mating pairs by other males. Therefore, hilltopping can be said to facilitate mating to whatever extent territorial behavior in general facilitates mating.

The above discussion deals with a particular aspect of hilltopping. Obviously, there are other reasons why insects, in congregations or singly, are to be found on hilltops. Apart from species that require arctic or subarctic conditions, which may be found on mountain tops, there are some that prefer a hilltop habitat for less obvious reasons. Often they are found on hills which are not high enough to provide alpine conditions, but since they are not found in the surrounding area, they cannot be called hilltoppers. On Vancouver Id., three species of Arctiid moths provide good examples of such behavior. They

are *Alypia ridingsi* Couper, *A. langtoni* Grt. and *Leptarctica californiae* Wlk.

Lastly there is the strange fact that hilltops are always likely places to turn up unusual locality records. I will not venture any theory to explain this phenomenon. From a number of my own interesting hilltop captures, both in the Lepidoptera and the Coleoptera, I will select the most remarkable as an example. I refer to the taking, on Mt. Arrowsmith in August of 1966, of a specimen of *Pieris sisymbrii* Bdv. The specimen was sent to Dr. dos Passos for positive identification. The species was not previously known to exist anywhere west of the coastal mountains in British Columbia. This individual had enough of the wing area torn off, on one side only, to seriously impede its flying ability.

LIST OF RHOPALOCERA SPECIES COLLECTED ON

MT. BENSON

Subspecific names omitted

<i>Papilio zelicaon</i>	<i>S. _____ californicus</i>
<i>Parnassius clodius</i>	<i>Incisalia iroides</i>
<i>Colias occidentalis</i>	<i>I. _____ fotis</i>
<i>Neophasia menapia</i>	<i>I. _____ eryphon</i>
<i>Cercyonis alope</i>	<i>Lycaena mariposa</i>
<i>Oeneis nevadensis</i>	<i>L. _____ helloides</i>
<i>Speyeria hydaspe</i>	<i>Everes amyntula</i>
<i>Boloria epithore</i>	<i>Plebeius melissa</i>
<i>Polygonia faunus</i>	<i>P. _____ icarioides</i>
<i>P. _____ zephyrus</i>	<i>Glaucopsyche lygdamus</i>
<i>Nymphalis milberti</i>	<i>Thorybes pylades</i>
<i>Vanessa atalanta</i>	<i>Pyrgus ruralis</i>
<i>V. _____ cardui</i>	<i>Erynnis icelus</i>
<i>Limenitis lorquini</i>	<i>Hesperia harpalus</i>
<i>Strymon melinus</i>	<i>Ochlodes sylvanoides</i>

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IDENTITY OF THE MOTH *LOXAGROTIS*
PAMPOLYCALA (DYAR) FROM THE
SOUTHWESTERN UNITED STATES AND MEXICO
(NOCTUIDAE)

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OVER THE PAST TWO DECADES or more, a species of *Loxagrotis* McDunnough near *L. socorro* (Barnes) has been collected in southern Arizona. It was thought to represent a new species, and only recently the author checked the types of similar species, including the type of *L. pampolycala* (Dyar), in the United States National Museum. The type male of *pampolycala*, U.S.N.M. type number 14210, described from Mexico, matches the series of the males before the author in every detail.

At the time of the original description of *pampolycala*, Dyar (1912) had only two specimens before him, a male and a female. In his discussion immediately following his original description, Dyar stated concerning the two specimens before him "The female before me is similar [to the male] . . .". The brackets are mine. From this statement, it seems obvious that the male should be selected as lectotype at the time of revisionary work.

McDunnough (1928) in his "A Generic Revision of North American Agrotid Moths" stated (p. 28) concerning four species of *Loxagrotis* "For the present *salina* Barnes, *capota* Sm., *albicosta* Sm., and *socorro* Barnes are placed here although the latter two are quite atypical, the palpi being heavily but smoothly scaled, not fringed with hair, and the genitalia of each showing a complete corona and considerable individual difference in the position and shape of the harpe." It is well to note that *pampolycala* also should be placed with this "atypical" group of the genus, namely with *albicosta* (Smith), *capota* (Smith), *salina* (Barnes) and *socorro* (Barnes).



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Fig. 1. *Loxagrotis pampolycala* (Dyar), male. Madera Canyon, Santa Cruz County, Arizona, 7 July 1963, Bauer-Buckett slide no. 69B25-33 (W. R. Bauer & J. S. Buckett).

Fig. 2. *L. pampolycala*, female. Data same as in fig. 1.

The synonymy of *pampolycala* under *socorro* is due to the work of Draudt (*in* Seitz, 1923). He states (*op. cit.*) "f. *pampolycala* Dyar belongs hereto, it is marked exactly the same, but more iron-grey in the ground-colour, without the dark filling of the cell and not so variable. The hindwing of the female is like that of the male whitish and hardly darkened. Mexico." The hindwing of the female, however, is somewhat darkened and can hardly be called "white".

Barnes and Benjamin (1924) followed this synonymy of *pampolycala* beneath *socorro*, however considered both species to belong to *Chorizagrotis* Smith, rather than to *Rhizagrotis* Smith as did Draudt. McDunnough (1928), was then the first author to place the concerned species in his newly erected genus *Loxagrotis*.

Loxagrotis pampolycala (Dyar)

Lycophotia pampolycala Dyar, 1912, Proc. U.S. Nat. Mus. 42:57-58.

Rhizagrotis socorro, form *pampolycala*, Draudt (*in* A. Seitz), 1923, Macrolepidoptera of the World, 7:51.

Chorizagrotis pampolycala, Barnes and Benjamin, 1924 (as a synonym of *socorro*), Contrib. Nat. Hist. Lepid. N. America 5(3):111.

Loxagrotis socorro, form *pampolycala*, McDunnough, 1938, Mem. Southern California Acad. Sci. 1:61.

DESCRIPTION: Male: Head with vertex and frons evenly rounded, slightly roughened, protruding; palpi exterolaterally blackish, basal segment colored ventrally with tan colored elongate hairs; apical portion of second segment light tan, third segment stubby, colored in tan scales; compound eyes with band of blackish hairs exterolaterally; antennae with scape and pedicel clothed in flattened tan colored scales; flagellomeres dorsally clothed with tan colored scales, ventrally fasciculate, apically becoming setose-ciliate. Thorax with collar composed of elongate dentate scales, basally tan, subapically somewhat darker, tan tipped; tegulae composed of flattened elongate tan colored scales and elongate brown simple hairs; disc composed predominantly of elongate tri-colored flattened hairs, basally tan, subapically brown, apically tan; ventrally clothed in elongate tan colored hairs; tarsi with segments clothed in black scales



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Fig. 3. *L. socorro* (Barnes), male. Sunnyside, west side, Huachuca Mountains, Cochise County, Arizona, 9 July 1958 (L. M. Martin).

Fig. 4. *L. socorro*, female. Madera Canyon, Santa Rita Mountains, Santa Cruz County, Arizona, 10 July 1957 (L. Stange and Harding).

except for apical annuli of tan colored scales; primaries with basal line represented costally as dark brown mark, thence by a single black dot on second anal vein; transverse anterior area with a longitudinal black elongate medial band; transverse anterior line hardly discernable and when visible appearing geminate, basally tan apically dark brown, course as in figure 1; medial area tan, overlain with dark brown scales; orbicular longitudinally elongated, tan, blending into tan costal band; reniform ovate, composed of light tan scales, outlined in dark brown scales, these scales coalescing with dark brown outline of orbicular; transverse anterior line scalloped, dark brown to black, course as in figure 1; subterminal area costally dark brown, thence tan colored, overlain with dark brown scales to inner margin, veins ventrally outlined in darker color; subterminal line very irregular, represented basally in dark brown, thence a band of tan scales terminally; terminal line composed of dark brown scallops between veins, these scallops being very shallow; fringes tri-colored, basally tan, medially dark brown, remainder off-white; ventral surface tan, with a suggestion of transverse posterior line in dark brown; secondaries whitish with a bluish tinge, costally tan colored; terminal line dark brown, fringes white; ventral surface as in dorsal surface except for presence of dark brown exterior band on costa. Abdomen dorsally clothed in elongate tan colored scales and simple hairs; ventrally clothed in tan colored scales and hairs which overlay broadened simple white colored scales. Greatest expanse of forewings 17 mm. Genitalia as in figures 5 and 6.

Female: As in male except antennae ciliate; secondaries dirty whitish overlain with brownish scales appearing almost fuscous, as in figure 2. Greatest expanse of forewings 18 mm. Abdomen dorsally clothed in brown broadened scales and simple hairs, posterior portion of segments clothed in light brown; ventrally clothed in off-white scales and hairs. Genitalia as in figure 9.

SPECIMENS EXAMINED: Mexico: Cotypes, no. 14210, U.S. Nat. Mus., 1 male, Cuernavaca, May, 1911 (R. Müller); 1 female, Guerrero, Mexico (J. Doll). Arizona: 1 male, 3 females, Madera Canyon, Santa Cruz County, 4880' elevation, 7 July 1963 (W. R. Bauer & J. S. Buckett); 2 females, same data as preceding, 8 July 1963; 1 female, Madera Canyon, Santa Cruz County, 16 July 1967 (C. W. Baker).

Specimens studied are deposited in the Entomology Department, University of California, Davis and the collection of the

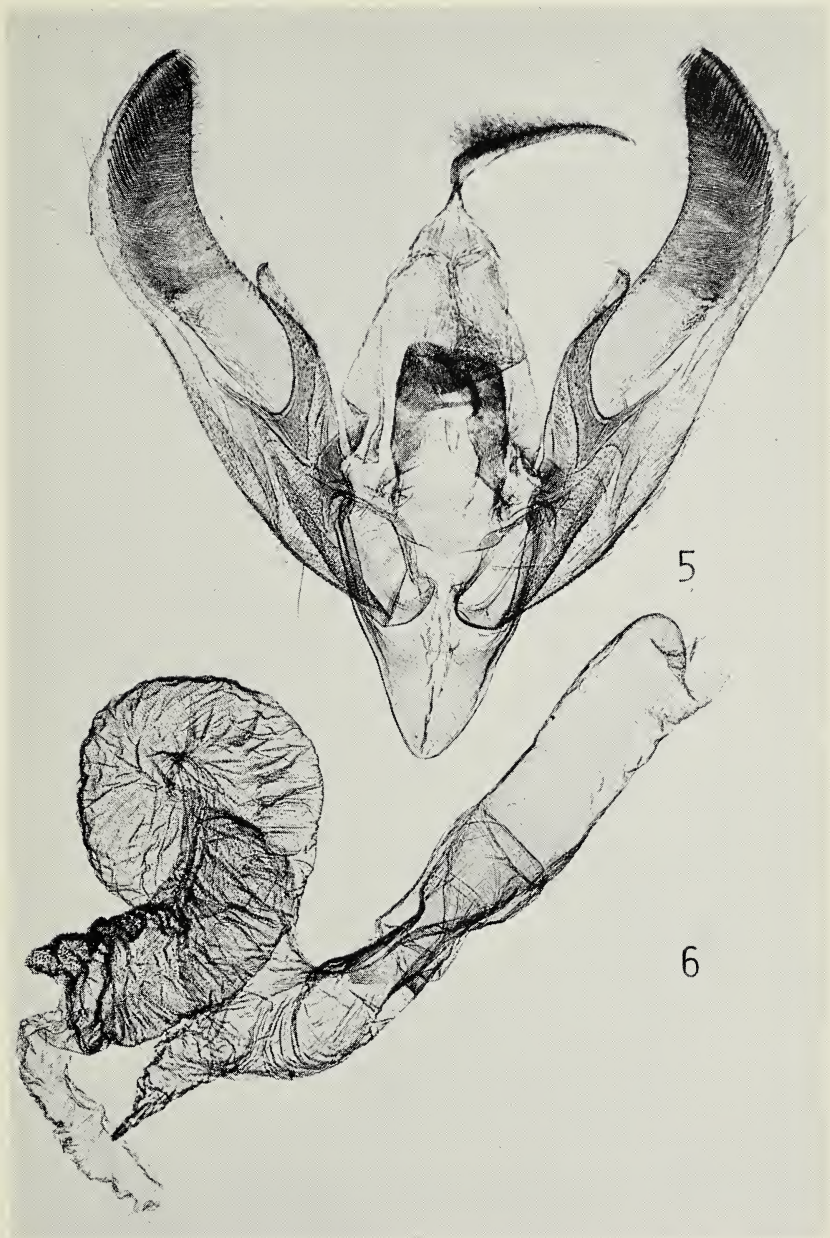


Fig. 5. *L. pampolycala*, male. Genitalia minus aedeagus. Data same as in Fig. 1.

Fig 6. *L. pampolycala*, male. Aedeagus, inflated, data same as in fig. 5.



Fig. 7. *L. socorro*, male. Genitalia minus aedeagus, Madera Canyon, Santa Cruz County, Arizona, 6 July 1963, Bauer-Buckett slide no. 69B25-31 (W.R.B. & J.S.B.).

Fig. 8. *L. socorro*, male. Aedeagus, inflated, data same as in fig. 7.

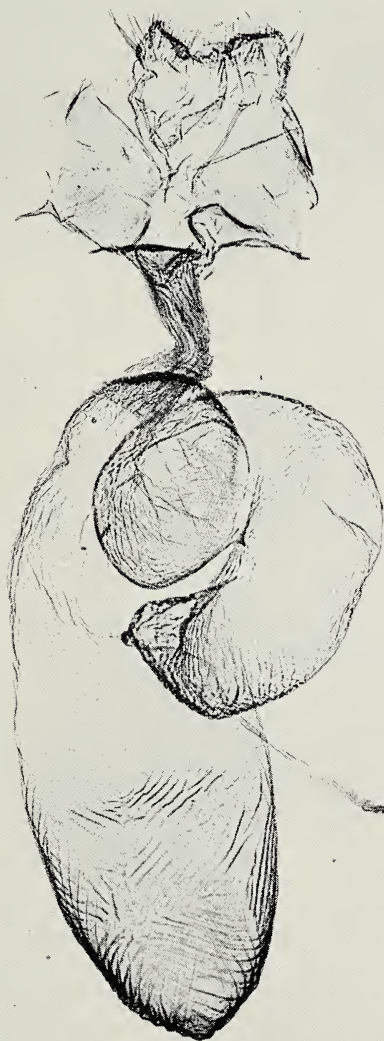


Fig 9. *L. pampolycala*, female genitalia. Madera Canyon, Santa Cruz County, Arizona, 8 July 1963, Bauer-Buckett slide no. 69B25-34 (W.R.B. & J.S.B.).

Bureau of Entomology California Department of Agriculture, Sacramento.

Loxagrotis pampolycala differs from its closest relative, *L. socorro* by being slightly larger, and more drab in coloration. Also, the reniform of *pampolycala* is larger and more in a diagonal position on the primaries, whereas the reniform of *socorro* is more upright on the wing. The secondaries of the females of *pampolycala* are darker than are those of *socorro* too. Both species occur sympatrically, and to my knowledge, nothing is yet known concerning the life histories of either species.

Loxagrotis socorro (Barnes)

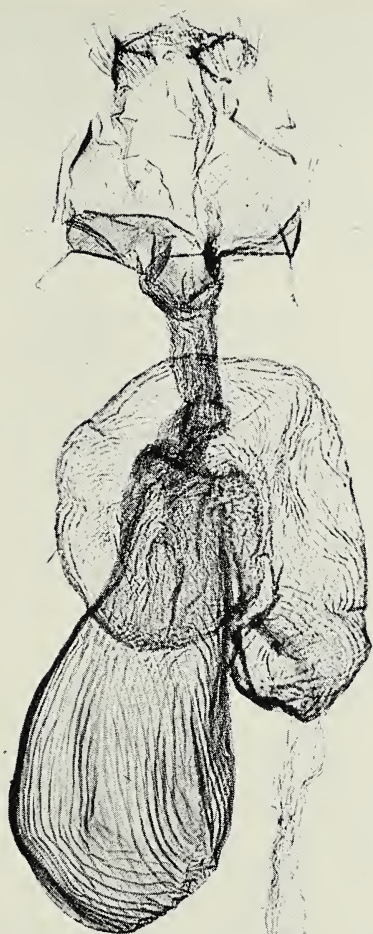
Rhizagrotis socorro Barnes, 1904, Canad. Entomol. 36(6):171-172; Barnes and McDunnough, 1912, Contrib. Nat. Hist. Lepid. N. America 1(4):16, pl. 6, fig. 20; Draudt, (in A. Seitz), 1923, Macrolepidoptera of the World 7:51.

Chorizagrotis socorro, Barnes and McDunnough, 1917, Checklist of the Lepidoptera of Boreal America, p. 44; Barnes and Benjamin, 1924, Contrib. Nat. Hist. Lepidoptera of N. America 5(3):111-112.

Loxagrotis socorro, McDunnough, 1928, Canad. Dept. Mines, Bull. no. 55, Biological series no. 16:27-28; 1938, Mem. Southern California Acad. Sci. 1:61.

DIAGNOSIS: Vestiture of head brown to dark brown; antennae of male fasciculate, terminally becoming setose-ciliate, of female ciliate. Thorax with divided collar possessing a dark transverse band; disc and tegulae clothed in various shades of brown; ventrally clothed in elongate whitish simple hairs; primaries dorsally with maculation as in figs. 3 and 4, ground color dark brown; costa with conspicuously cream colored band, from base to just past reniform; reniform ochreous, centrally filled with dark brown scales; subterminal area conspicuously washed with whitish scales, contrasting with median and dark brown terminal areas; secondaries whitish with purplish sheen in male, in female there is tendency toward dirty white or fuscous. Greatest expanse of forewings 15-16 mm. Genitalia as in figs. 7, 8, and 10.

SPECIMENS EXAMINED: Arizona: 1 male, Madera Canyon, Santa Cruz County, 4880' elevation, 6 July 1963 (W. R. Bauer & J. S. Buckett); 2 females, same data as preceding, 7 July 1963; 1 female, same data as preceding, 8 July 1963; 1 female, same data as preceding, 14 July 1963; 1 female, Madera Canyon, Santa



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Fig. 10. *L. socorro*, female genitalia. Madera Canyon, Santa Cruz County, Arizona, 7 July 1963, Bauer-Buckett slide no. 69B25-32 (W.R.B. & J.S.B.).

Rita Mountains, Santa Cruz County, southern Arizona, 10 July 1957 (Stange and Harding); 1 male, Sunnyside, west side Huachuca Mountains, Cochise County, ex. 15 watt fluorescent black light, 8 July 1958 (Lloyd M. Martin); 1 female, same data as preceding, 9 July 1958; 1 male, same data as preceding, 12 July 1958.

L. socorro may be distinguished from its closest relative, *L. pampolycala* by use of the characters in the discussion section under *pampolycala*, as well as by use of the genitalia.

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RECORDS OF
COLIAS GIGANTEA STRECKER (PIERIDAE)
FROM SOUTHEAST MANITOBA
AND ? MINNESOTA

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HOVANITZ (1950) RECORDED THE KNOWN RANGE of *Colias gigantea* Strecker as subarctic North America, from the northern limit of trees in Alaska east to Hudson Bay; southward, in willow bogs, to southern Canada, from the Rockies in Alberta eastward to the Manitoba Escarpment; then on south in the Rockies (as *scudderii* Reakirt) to Colorado and New Mexico—but suggests a possible range extension eastward to northern Minnesota, Wisconsin and Michigan in willow bogs. Up until now the only recorded range extension recorded was by Riotte (1962) who recorded specimens from three points on Hudson Bay in Ontario that extended the range eastward from Churchill to Fort Albany on James Bay. John Polusny, of Winnipeg (in litt.) reports a few solitary specimens of *Colias gigantea* in southeast Manitoba; but it is only recently that I have been able to confirm that it occurs south of the 53rd parallel, east of Lake Winnipeg.

On 8-10 August, 1969, I collected 5 males and 2 females of *Colias gigantea* at three localities between the O'Hanley and Sand (sometimes called Sandy) Rivers along Manitoba highway 304. These locations are just east of Lake Winnipeg and are between the 50th and 51st parallel. All of the specimens were taken in wet sphagnum/willow bogs and all were somewhat worn in condition. The determination of the females leaves little room for doubt: one of them is "white" with wing borders completely immaculate of black (this is a common variant situ-

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Fig. 1. Probable *Colias gigantea* Strecker. Male taken 2 August 1967 by W. A. Bergman near McNair, Lake County, Minnesota. Upper side above, lower side below. 175 percent actual size.

ation with female *gigantea*) while the other female is yellow with fully developed, but weakly scaled, black borders. The five males are distinguished from *C. interior* (with whom they are superficially very similar) by their larger size and association with willow bogs and the indicated females. A few specimens of *Colias interior* Scudder were taken in nearby locations. They were quite worn and tattered, indicating that *C. interior* probably has an earlier flight here than *C. gigantea*. The southeastern Manitoba specimens of *Colias gigantea* are very close in appearance to *Colias gigantea mayi* Chermock & Chermock from Riding Mountain, Manitoba. Like *mayi* they lack the heavy dark scaling on the ventral hindwing that is usually used as an identification character for *Colias gigantea*. Because of this, the key to *Colias* by Klots (1961) is ineffective for separating them into *gigantea*—the confusion resulting at couplet 4a-4b.

On August 2nd, 1967, Bill Bergman of Minneapolis collected a very large male *Colias* at McNair, Lake County, Minnesota. He was collecting along a railroad track that borders a bog when he noticed the butterfly in flight because of its apparently large size. After mounting the butterfly he asked me to examine it thinking it might be *C. gigantea*. In *Colias* a definitive determination of a single specimen is often impossible and until more Minnesota examples are collected we cannot be 100% positive that this specimen is indeed *gigantea*. However, in my own mind I am fairly certain that it is *gigantea*. The butterfly was taken in a potentially suitable habitat for *gigantea*, has a large wing expanse (29 mm. base to tip of forewing which is larger than any specimen of *C. interior* that we have seen from Minnesota), and while the specimen is quite worn, the markings (see figure 1) seem to fit in better with a series of *gigantea* than they do with *interior*. There are a couple of large male *Colias* in the John Nordin Collection, at Webster, South Dakota, which were taken in Koochiching County, Minnesota that also might prove to be *gigantea*. The Bergman specimen from Lake County has been placed in the American Museum of Natural History in New York City.

In addition to the specimens of *C. gigantea* mentioned in the preceding, I have taken several dozen specimens along the Manitoba Escarpment from Riding Mountain northward in western Manitoba. My preliminary field data suggests that the species may be associated with string bogs. String bogs are peculiar in that they are topographically aligned in strips up

and down slope. The climatic and edaphic conditions necessary to produce string bogs is not understood, but it is clearly different from the lake fill succession that is normally accepted for bogs south of the 53rd parallel. Most bogs north of the 53rd parallel are a result of the underlying permafrost that prevents water drainage through the top soil. String bogs, by nature of their being topographically aligned, can be assumed to have groundwater movement which may favor, at least in some areas, the growth of willows over black spruce. Heinselman (1963) records the presence of string bogs as far south as the north shore of Red Lake in Minnesota and (1965) at an isolated spot near Seney, Michigan. It would be interesting if the range of *Colias gigantea* continues to correspond with the areas in which string bogs occur as both of them become better known.

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THEORIES ON THE NATURE OF LIFE. Giovanni Blandino, S.J. Philosophical Library, N.Y.

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WANTED:

Brephidium exilis, *B. fea*, *B. isophthalma*. Life material and specimens for distribution study. Roy Jameson, 2429 Wordsworth, Houston, Texas 77025.

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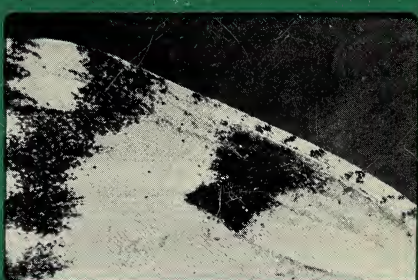
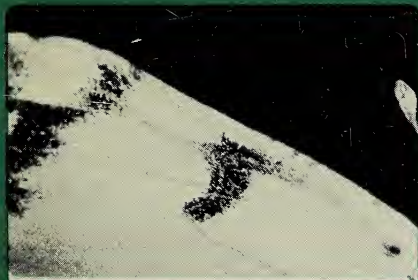
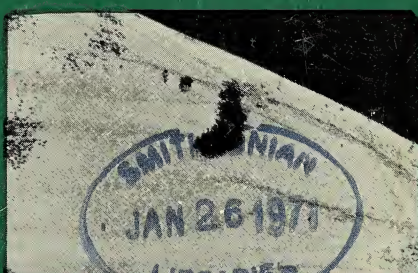
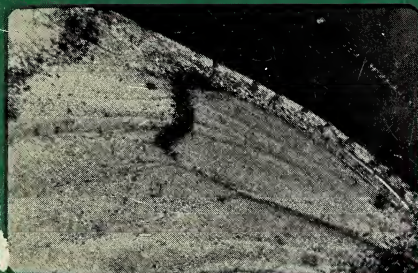
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SEASONAL CHANGES IN ORGANIZATION OF TROPICAL RAIN FOREST BUTTERFLY POPULATIONS IN PANAMA

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SEASONALITY IS USUALLY CONSIDERED a distinctive feature of temperate zone communities, with their fluctuating annual climates, while the wet lowland tropics are relatively constant in most environmental conditions. Yet major seasonal changes in tropical plant communities have been demonstrated for even rain forest areas and the selective reasons for this seasonality are beginning to be explored (e.g., see Janzen 1967). The possible existence of seasonality in the animals of tropical communities has barely been touched upon to date, most available data being on birds (e.g., Skutch 1950, Moreau 1950, Miller 1954, Ricklefs 1966, Leck 1970), certain tropical lizards (Hirth 1963, Alcalá 1966, Sexton 1967) and foliage-inhabiting insects (Janzen, unpublished; Hespénheide, unpublished). These studies have shown there may be significant changes in vertebrate population size and reproductive activities even in tropical forests with a constant annual climate. Differences in population density and species composition of foliage-inhabiting insect communities have been shown (by Janzen and Schoener 1968) between wetter and drier sites in a tropical deciduous forest, while the dry season has been shown to decrease population density of inflorescence-feeding *Drosophila* in Panama (Pipkin, Rodríguez and León 1966). Most mosquito species studied by Bates (1945) in tropical eastern Colombia showed seasonal fluctuations in population density. Yet there has been little documentation of the recent textbook assertion (Boughley 1968: p. 40) that "Marked seasonal fluctuations in population density are encountered as frequently

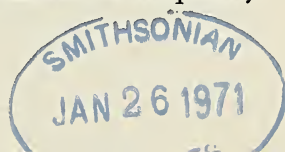




Fig. 1.—Map of Barro Colorado Island, Canal Zone, showing location of 1968-69 study areas (Laboratory Clearing and Forest trail).

in tropical . . . regions as they are in temperate." Moreover, detailed data on seasonal changes in species composition of a major animal group aside from birds (Slud 1960) are lacking for the tropical rain forest in the Americas.

The existence of seasonal change in species composition, as well as number of individuals, is a standard feature of temperate communities, especially among the arthropods but even vertebrates (e.g., birds). One group of insect species is characteristic of the spring fauna, another group of species replaces them in early summer, and so on with the changing temperature regime and food availability. However, the tropical species in rain forests would be expected to breed all year if constant temperature was the principal requirement for continuous breeding. A stable species composition in any one area should result; that is, the same group of species should be present all year. On the other hand, fluctuations in population density and even species composition could be expected from possible seasonal variation of rainfall, humidity, light intensity as affected by cloudiness, and other environmental conditions in the rain forest.

With about 4,000 species in tropical America (Seitz 1913) out of a world fauna of 12-15,000 species and their suggested impact upon evolution of the angiosperms (Ehrlich and Raven 1965), butterflies definitely qualify as a major tropical animal group of considerable ecological interest. This study examines the dynamics of faunal composition in the resident butterflies of the tropical rain forest in Barro Colorado Island, Panama, with respect to seasonal changes in active species and changes in population density from the latter half of the wet season (October-November 1968) through the major portion of the dry season (December 1968-March 1969). The viewpoint that tropical species diversity may be influenced by a "seasonal ecotone" or edge effect at the period of wet-to-dry-season transition is suggested by these faunal changes in Panamanian butterflies.

DESCRIPTION OF STUDY AREAS AND METHODS

This research was conducted on Barro Colorado Island in Gatun Lake, Canal Zone, Isthmus of Panama, from October 1, 1968, through April 12, 1969. The island is largely covered with rain forest having a canopy starting at about ninety feet. The annual rainfall is about 2700 mm at the Smithsonian Tropical Research Institute station (Moynihan, 1968). Further descriptions of the general vegetation and climate may be found in Allee (1926a, 1926b).

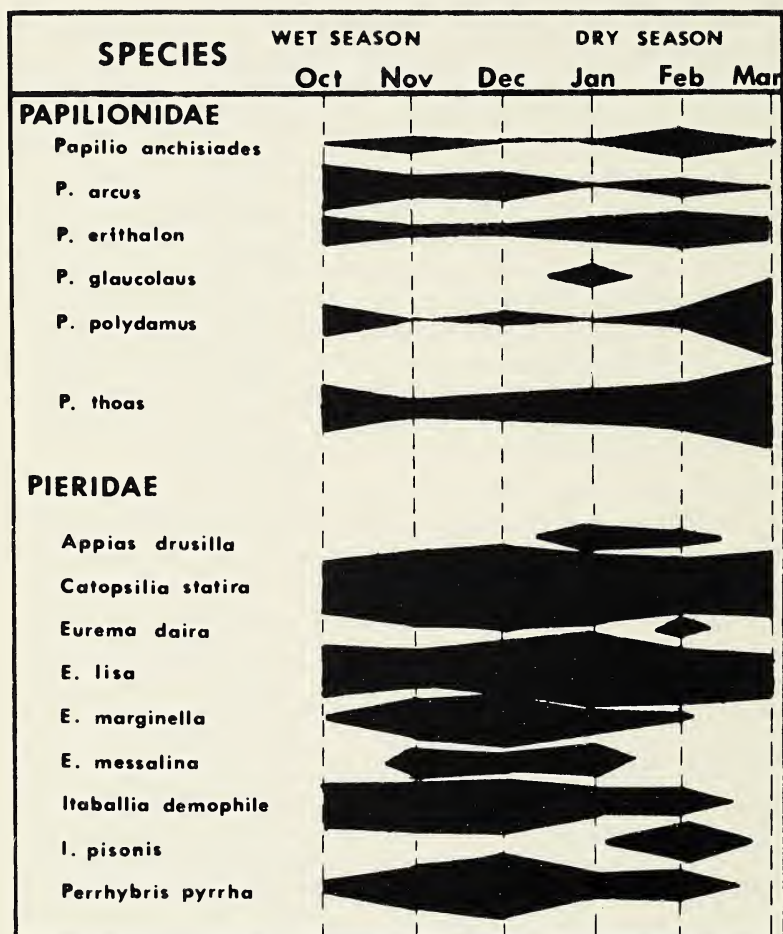


Fig. 2.—Patterns of flight activity of adult populations of butterflies in the Families Papilionidae and Pieridae, Clearing study area, October 1968 to the end of February 1969. The width of the bar indicates relative adult population density for a given species during each month (number of days species was observed out of total number of observation days).

Clearing Study Area. Most of the data reported herein were collected in the clearing extending from slightly southwest of the Smithsonian Tropical Research Institute field station north-eastward to the shore of Gatun Lake, at 9°09'50" north latitude and 79°50'25" west longitude (see Fig. 1). This clearing measures about 778 m by approximately 286 m (the width varies considerably); the elevation at the southwestern end is 35 m higher than the northeastern end at the Gatun Lake shore line (26 m above sea level). Since its establishment, the size and condition of the clearing has varied considerably through the years. Presently it is maintained in the early stages of succession, much as described by Kenoyer (1929): (1) In small areas about the buildings frequent cutting permits only grasses and annual weeds. (2) In much of the clearing where cutting occurs infrequently, plants of the second-year association are common (e.g. *Heliconia* and *Piper*). (3) Along the edges and in neglected patches throughout the clearing, species of the "pioneer forest" (e.g. *Cecropia*, *Ochroma*, and *Tetracera*) dominate. (4) Within the whole area introduced plants are important (e.g. *Citrus*, *Hibiscus*, *Ixora*, *Musa*, *Psidium*, and others).

Censusing of butterfly species was carried out for two hours daily on census days: one hour between 0900 and 1200, and one hour between 1300 and 1500. Specific hour periods were rotated regularly. Only 4 lycaenid and 2 hesperiid species were censused; otherwise, all species present were recorded. Field identification of flying butterflies was considered quite accurate (all species identifications were originally verified by collected specimens). All censusing was done by the second-named author (C.F.L.).

Forest Study Area. Within the rain forest species censuses were conducted weekly to record changes in forest-restricted butterfly populations. The 2,050 m trail route indicated in Figure 1 was censused from 0800 to 1030; no afternoon censuses were taken. This route ran west of the C.C.I. Laboratory on the Lathrop trail, then south and east on the Miller, Wheeler, and Snyder-Molino trails, and north on the last-named trail to the laboratory again.

RESULTS

The Clearing study area provided census data on 92 species of butterflies; these are summarized in Table 1. The relative abundance or relative population density of each species per

TABLE 1

Flight activity patters in wet and dry seasons for butterfly species in Clearing study area, October 1968 through February 1969. Figures represent percentage of total census days in a month that each species was recorded.

		Relative Adult Population Density of Species*				
FAMILY	Species	WET SEASON		DRY SEASON		
		October	November	December	January February	
PAPILIONIDAE: 6 species						
	Papilio anchisiades	--	4	--	--	4
	P. arcus	58	22	20	--	14
	P. erithalon	25	9	5	13	27
	P. glaucolaus	--	--	--	9	--
	P. polydamus	12	--	5	--	11
	P. thoas	17	9	14	35	68
PIERIDAE: 10 species						
	Appias drusilla	--	--	--	26	14
	Phoebis statira and argante	42	74	82	87	77
	Eurema daira	--	--	--	--	9
	E. lisa	75	61	77	87	64
	E. marginella	--	31	55	12	5
	E. messalina	--	9	5	17	--
	Itaballia demophile	50	83	86	13	18
	I. pisonis	--	--	--	--	18
	Perrhybris pyrrha	4	57	68	13	23
DANAIDAE: 21 species						
	Dabaus gilippus	4	--	--	--	5
	Lycorea cleobaea	8	--	--	--	--

Table 1: Continued

	Oct.	Nov.	Dec.	Jan.	Feb.
ITHOMIIDAE: 6 species					
<i>Aeria eurimedia</i>	--	--	5	--	11
<i>Hypoleria libera</i>	--	--	5	--	--
<i>Hypothyris euclea</i>	--	4	5	4	--
<i>Mechanitis franis</i>	--	--	9	--	--
<i>M. isthmia</i>	--	--	--	35	9
<i>Tithorea tauracina</i>	--	--	--	13	--
SATYRIDAE: 10 species					
<i>Antirrhaea miltiades</i>	--	--	5	--	--
<i>Callitaera menander</i>	17	17	9	4	--
<i>Euptychia antonoe</i>	--	--	--	9	14
<i>E. gulnare</i>	4	--	5	13	5
<i>E. hermes</i>	96	87	100	87	45
<i>E. hesione</i>	4	9	5	4	--
<i>E. juani</i>	--	4	--	--	9
<i>E. labe</i>	--	--	5	--	--
<i>E. molina</i>	75	43	53	65	68
<i>Pierella luna</i>	13	17	14	9	18
BRASSOLIDAE: 4 species					
<i>Caligo</i> sp.	8	--	5	--	--
<i>Eryphanis polyxena</i>	--	4	5	13	9
<i>Orsiphanes fabricii</i>	--	--	5	--	--
<i>O. xanthicles</i>	13	4	--	4	--
MORPHIDAE: 3 species					
<i>Morpho peleides</i> and <i>amathonte</i>	50	44	41	39	50
<i>M. theseus</i>	--	4	18	17	--

Table 1: Continued

	Oct.	Nov.	Dec.	Jan.	Feb.
HELICONIIDAE: 13 species					
Colaenis (Dryas) julia	42	52	91	70	64
Dione juno	29	13	9	--	--
D. vanillae	--	--	--	--	5
Heliconius (Eueides) aliphera	--	13	--	9	--
H. (E.) isabella	17	--	--	4	27
H. (E.) lybius	--	--	--	4	--
Heliconius cydno	54	70	68	50	59
H. doris	--	--	5	30	5
H. erato	88	70	77	78	86
H. ethillius	58	35	32	35	17
H. sappho	--	--	--	--	9
H. sara	71	70	68	57	23
Metamorpha dido	4	--	--	--	--
NYMPHALIDAE: 21 species					
Adelpha iphicleola	--	4	5	4	5
A. marcia	8	4	14	22	9
Ageronia (Hamadryas) februa	4	13	--	--	5
Anartia fatima	100	100	100	100	100
A. jatrophae	71	13	23	74	91
Callicore sp.	--	4	5	--	--
Catagramma sp. (peralta?)	4	--	--	--	--
C. titheas	--	4	--	4	--
Catonephele numilia	--	9	5	--	--
Myscelia cyaniris	--	--	9	--	5
Phyciodes clio	--	--	5		

Table 1: Continued

	Oct.	Nov.	Dec.	Jan.	Feb.
<i>P. leucodesma</i>	8	--	9	4	--
<i>P. ofella</i>	--	--	9	--	--
<i>Precis lavinia</i>	--	4	5	--	--
<i>Prepona</i> sp.	--	--	--	4	--
<i>Protopogonius fabius</i>	13	--	--	4	--
<i>Pyrrhogyra crameri</i>	--	--	5	4	--
<i>Taygetis uncinata</i>	8	--	--	9	5
<i>Temenis libera</i>	4	48	27	30	14
<i>Marpesia chiron</i>	8	--	9	17	--
<i>Victorina steneles</i>	--	4	27	26	--
RIODINIDAE: 11 species					
<i>Calephelis virginiensis</i>	--	4	--	--	--
<i>Charis chrysus</i>	--	4	--	--	--
<i>Eurybia patrona</i>	--	--	5	--	--
<i>Euselasia</i> sp.	--	--	5	--	--
<i>Hades noctula</i>	--	--	5	--	--
<i>Ithomeis eulema</i>	--	--	--	--	9
<i>Mesosemia</i> sp.	4	--	--	4	--
<i>M. telegone</i>	13	13	--	--	--
<i>Nymula phylleus</i>	--	--	--	--	4
<i>Oleria paula</i>	4	4	--	--	9
<i>Zelotaea pellex</i>	--	--	5	--	--
LYCAENIDAE: 4 species tallied					
<i>Strymon yojoa</i>	--	--	--	--	4
<i>Thecla hemon</i>	--	--	--	--	4
<i>T. jalan</i>	--	--	--	--	4

Table 1: Continued

	Oct.	Nov.	Dec.	Jan.	Feb.
<i>T. togarna</i>	--	--	--	--	14
HESPERIIDAE: 2 species tallied					
<i>Eudamus</i> sp.	--	4	5	65	27
<i>Hesperia syrichtus</i>	50	13	32	52	77

TOTAL: 92 species tallied in Clearing

*The index of relative population density of each species is recorded as the frequency of occurrence out of the total number of census days each month (see text). The numbers of census days per month, 1968-69, were: October (24), November (23), December (22), January (23), February (22). The wet season extends from June to mid December, the dry season from late December to May (see text).

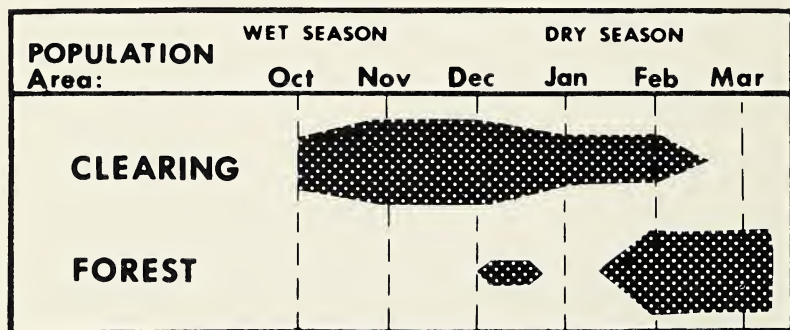


Fig. 3.—Pattern of relative flight activity in the Clearing and Forest areas. of the pierid butterfly, *Itaballia demophile*.

month is indicted as a percentage:

$$\frac{\text{Number of days sp. recorded}}{\text{Total no. of census days that month}} = \frac{\text{Index of Relative Abundance}}{\text{(Percentage of census days each sp. was recorded)}}$$

That is, the commoner a species the higher the probability that it will show up in all census periods. For example, *Anartia fatima* (Nymphalidae) was the only species observed on all census days every month (index value of 100%), while *Papilio anchisiades* was only seen on one out of 23 days in November (index = 4%) and one out of 22 census days in February (Table 1); hence the latter species' population density was comparatively very low. The Clearing area was too large and time too limited for capture-recapture determinations of absolute population densities. However, the present method at least allowed an accurate estimate of variations in adult population density from month to month. The data for the period from October 1968 to February 1969 were collected on a comparable number of days (22 to 24; see Table 1). Only five census days were available for March 1969, and the data are not tabulated here though they support the same general trends already evident in the dry-season censuses.

The Forest study area supported a much smaller fauna; census data on the 23 species observed are given in Table 2. Here, actual numbers are given because of the variable number of census days per month and the low forest population densities which made sampling errors relatively more important.

The average rainfall and duration of wet and dry seasons for the last forty years on Barro Colorado Island are given in Table 3. The rainfall during the present study, September 1968 to March 1969, is given in Table 4. It is clear from a comparison of the two tables that the dry season began somewhat earlier than usual in 1968-69, but that December is a transition period between the end of the heaviest rains (in November) and the start of the dry season which come towards the end of December.

The data in Table 5 indicate that our censusing procedure included a full representation of the butterfly fauna of Barro Colorado Island, with the exception of the two groups of small, often secretive or fast-flying species in the families Lycaenidae and HesperIIDae.

TABLE 2. Flight activity patterns in wet and dry season for butterfly populations in Forest study area, October 1968 through March 1969.

Forest Route:		Number of Individuals Censused on Each Date:																							
		Oct.						Nov.						Dec.						Jan.					
Species*		14	1	9	16	28	5	16	30	7	14	21	27	2	8	16	22	1	8	15	22	28			
1.	Callitaera menander	1	1	2		1																			1
2.	Pierella luna		5	7	3	4	4	1		2	1	2	2	3	2	1	2	4			1	1	4		
3.	Caligo sp.	1																	1			1	1		
4.	Morpho sp. (blue)	3			1	1	1			1			1		1	2	1	5	4	2	1				
5.	Adelpha iphicleola		1																						
6.	Mycalesia cyaniris								1																
7.	Itaballia demophile							1		2															7
8.	Heliconius cydno							1																1	2
9.	Euptychia hesione								1					2				1	1	3	5	1			
10.	Taygetis uncinata												2					1	3						
11.	Eriphanes polyxena												1												
12.	Euptychia juani													1											
13.	Heliconius sappho													2											
14.	Aeria eurimedia													1				1	2						1
15.	Itaballia pisonis																								
16.	Antirrhoea miltiades													2	3	5	1	1							
17.	Mechanitis sp.																	1							
18.	Euptychia antonoe																								1
19.	Thecla sp.																								
20.	Catagramma denina																								1
21.	Terias lisa																								
22.	Colaenis julia																								1
23.	Temenis libera																								1

*Species arranged in order of appearance during forest-survey period, not in taxonomic groups.

TABLE 3. Rainfall in wet and dry seasons on Barro Colorado Island, Canal Zone, Isthmus of Panama (Station average, 1925 or 1926 to 1966; data calculated from Moynihan, 1968).

<u>Month</u>	<u>Station Average Rainfall in mm.</u>
<u>WET SEASON</u>	
May	276.6
June	276.9
July	293.9
August	329.7
September	262.6
October	347.5
November	461.3
December	269.2
<u>DRY SEASON*</u>	
January	57.7
February	32.5
March	29.2
April	88.4
ANNUAL TOTAL	2,712.7
DRY SEASON: TOTAL:	207.8
WET SEASON: TOTAL:	2,504.9

*Dry season generally starts in latter half of December. The median date for the beginning of the dry season is about December 20.

Table 4

Rainfall in the 1968-69 study period on Barro Colorado Island, Canal Zone (unpublished data from Panama Canal Company, Engineering and Construction Bureau, Meteorological and Hydrographic Branch).

<u>Month</u>	<u>Station Rainfall in mm.</u>
September 1968	179.8
October	474.0
November	262.1
December	46.2
January 1969	44.2
February	13.2
March	10.9

DISCUSSION AND CONCLUSIONS

There were far greater number of butterfly species and individuals active in the Clearing than in the Forest study areas, both in the wet season and dry season. Part of the explanation is likely an "overflow" effect, where many of the species that normally fly high in the forest canopy come down low over the clearing and are noted, but remain on top of the canopy and thus unrecorded in the forest. Further reasons for the abundance of species in the clearing undoubtedly lie in the heliothermic and thus heliophilic nature of butterfly physiology and behavior (Emmel and Emmel 1962, 1963, 1964; Clench 1966; Watt 1968). Most species, even in the tropics, require direct sunlight to raise their body temperatures above ambient levels for flight. The clearing also provides a much greater variety of nectar sources for adult feeding, and a much greater variety of second-growth plants commonly used as larval foodplants in such groups as the Pieridae, Nymphalidae and Heliconiidae.

1. *Seasonal fluctuations in population size*

There were considerable fluctuations in population size from month to month for most species of butterflies on Barro Colorado Island. These changes were usually associated with the change from wet season to dry season, species flying mainly in one season (within the limits of the present survey). However, many species reached their population peaks during the transition period between wet and dry seasons. Fluctuations in populations of papilionid and pierid butterflies are shown in Figure 2. These changes may be due partly to changes in condition of larval food, such as has been advanced as an explanation of fluctuations in tropical *Drosophila* populations (Pipkin 1953) where major variations in population size follow variations in the local food supply.

It is clear that later in the dry season, by the month of March, the grasses and herbs of the Clearing area become very dry or if still green, new growth has halted. Populations of some butterflies, such as the pierid *Itaballia demophile*, actually shift their activity into the cooler more humid forest from the clearing when the dry season is well underway (see Fig. 3). This shift from open areas to the forest probably accounts for the increase in number of species in the forest fauna in the dry season (Fig. 4, lower portion), although the dry season also probably presents more favorable environmental conditions for adult flight

Table 5. Comparison of species recorded in the butterfly fauna of Barro Colorado Island by Huntington (1932) and those censused in the present study.

FAMILY Group	Huntington	Present Study
Papilionidae	5 species	6 species
Pieridae	13	10
Danaidae	4	2
Ithomiidae	11	6
Satyridae	16	10
Brassolidae	2	4
Morphidae	2	3
Heliconiidae	12	13
Nymphalidae	27	21
Riodinidae	40	11
Lycaenidae	34	4*
Hesperiidae	99	2*

* = only these species censused; others observed.

and reproductive activities for the permanent forest species.

As just suggested, the influence of rainfall on adult activity may also play an important role in causing seasonal population fluctuations. The total number of hours of sun per day available to the butterflies for flying and reproductive activity was considerably less in the wet season than in the dry season due to afternoon cloudiness and rain. In a long-term or seasonal sense, then, it is selectively advantageous to have a species' main flight period in a time other than the wettest part of the rainy season. The most advantageous time to fly and reproduce during the year would seem to be the period immediately following the close of the wet season, for later in the dry season (when environmental conditions are still excellent for adult activity) the larval foodplants may not be in suitable condition for feeding by newly-hatched larvae. The apparent reality of this supposition is reflected in the following data on changes in faunal organization from the wet season to the dry season.

2. *Seasonal fluctuations in species diversity.*

When the number of species flying in the Clearing and Forest study areas are graphed for each month (Fig. 4), it is clear that (1) diversity in the Forest area increases in the dry season but it is still at a relatively low level compared to that of the Clearing fauna, and (2) diversity in the Clearing fauna, containing clearly the species requiring a higher level of sunlight for activity, reaches a *maximum diversity* during the *Transition Period* immediately following the Wet Season, before the Dry Season conditions fully prevail.

This surprising confirmation of the preceding suppositions (section 1) leads us to propose this as an example of a perhaps more widespread phenomenon in the tropics: a "Seasonal Ecotone." An ecotone, simply defined, is merely "a transition area between two adjacent communities" (Webster's New Collegiate Dictionary). Treating the wet-season butterfly fauna and the dry-season fauna as separate communities, the transition period between the wet and dry seasons may be called a "Seasonal Ecotone," and is simply a temporal analogy of the spatial concept of an ecotone. This seasonal ecotone may be a general phenomenon in influencing tropical species diversity, in that one could find the greatest number of active species (of short-life-cycle animals) between two distinct seasons, merely because both wet and dry season communities may be represented. The broader application of the seasonal-ecotone concept is currently being considered for a number of tropical and

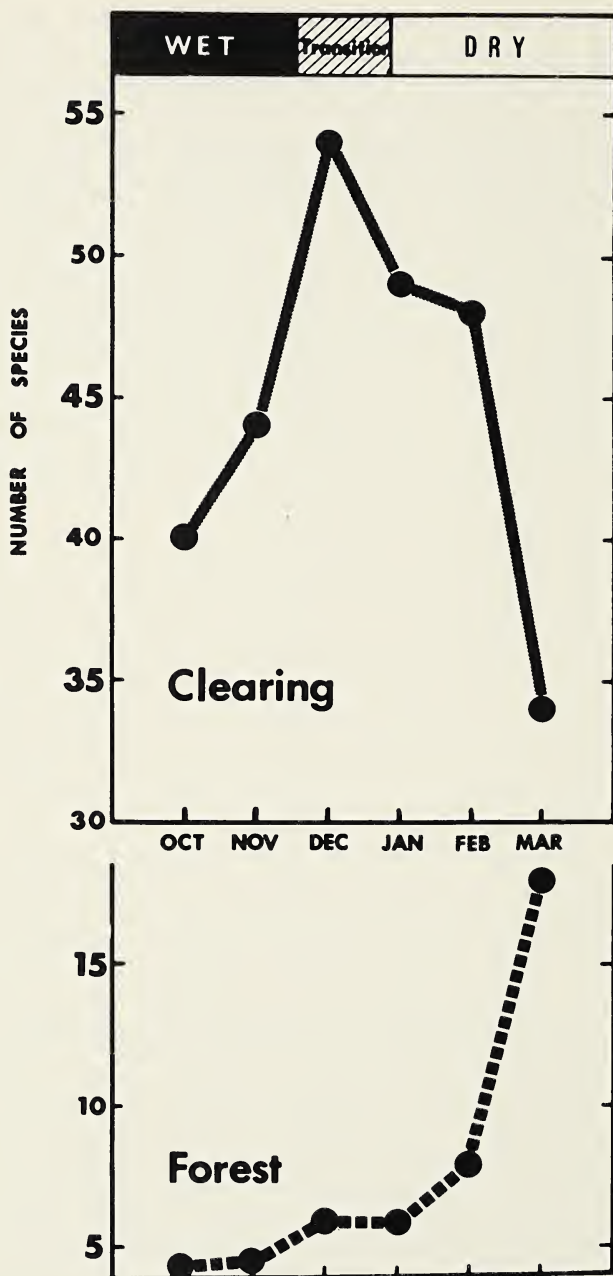


Fig. 4.—Number of butterfly species observed in Clearing (top) and Forest (bottom) study areas per month from wet to dry season, 1968-1969.

temperate animal groups (Emmel, in preparation). However, it is clear with diurnally-active insects such as the butterflies that the most reproductively favorable conditions also may exist at this time and hence the seasonal ecotone fauna does not merely represent an overlapping of communities but one which has responded in an evolutionary sense to the most satisfactory breeding period during the annual cycle (which exists even in a tropical evergreen forest.) Preliminary review of data from Costa Rican sites and elsewhere (Emmel, in preparation) indicates that diversity increases only at the gradual wet season-dry season seasonal ecotone (December in the northern Neotropics), not at the sharp point of dry season-wet season transition (April or May in the northern Neotropics). This presumably is the result of dry-season-species' adult intolerance of the rainy conditions suddenly initiated by the start of the wet season.

SUMMARY

Butterfly faunal censuses were made in a large clearing and in the rain forest on Barro Colorado Island, Panama, during the wet season and dry season, 1968-69. There were significant changes in both population densities and species composition (as represented by flying adults) from month to month and between climatic seasons at this tropical site. These fluctuations are apparently associated with available sunlight for thermoregulation and with condition of larval hosts.

The greatest number of species flies at the transition period between the wet and dry seasons. This "seasonal ecotone" is probably due to both an overlapping of dry- and wet-season faunas and to the favorable junction of environmental factors for adult activity by tropical butterflies at that particular time.

ACKNOWLEDGMENTS

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STUDIES ON NEARCTIC *EUCHLOE*. PART 6. SYSTEMATICS OF ADULTS

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THIS PAPER PRESENTS A DISCUSSION of some external morphological features of the adults of Nearctic *Euchloe*, a key to identification, descriptions of named entities, and illustrations. Stress will be given those features found most useful in the separation of adults.

METHODS

CHROMATOGRAPHY. The procedures followed were based on those of Hadorn and Mitchell (1951) and Biserte (1960). Solvent systems of n-Propanol and aqueous ammonia (2:1) and Butanol, glacial Acetic acid, and water (4:1:5) were employed. The chromatograms were obtained by a uni-directional ascending method and the spots were revealed under ultra-violet illumination.

EXTERNAL FEATURES. With the exception of androconial scales, all external features were studied with the aid of a dissecting microscope at 10, 30, or 60 power.

Measurements of wing length were made with a vernier caliper to the nearest one-tenth millimeter. Measurement of costal length was made from the point of wing attachment to furthest extent of the apex, not including the fringe.

The width of the black bar at the end of the cell on the dorsal surface of the forewing was measured by counting the number of scale rows on the right wing under 30 power from the first row with 50% or more black scales to the first comparable row on the opposite side. The number of white scales in the bar were

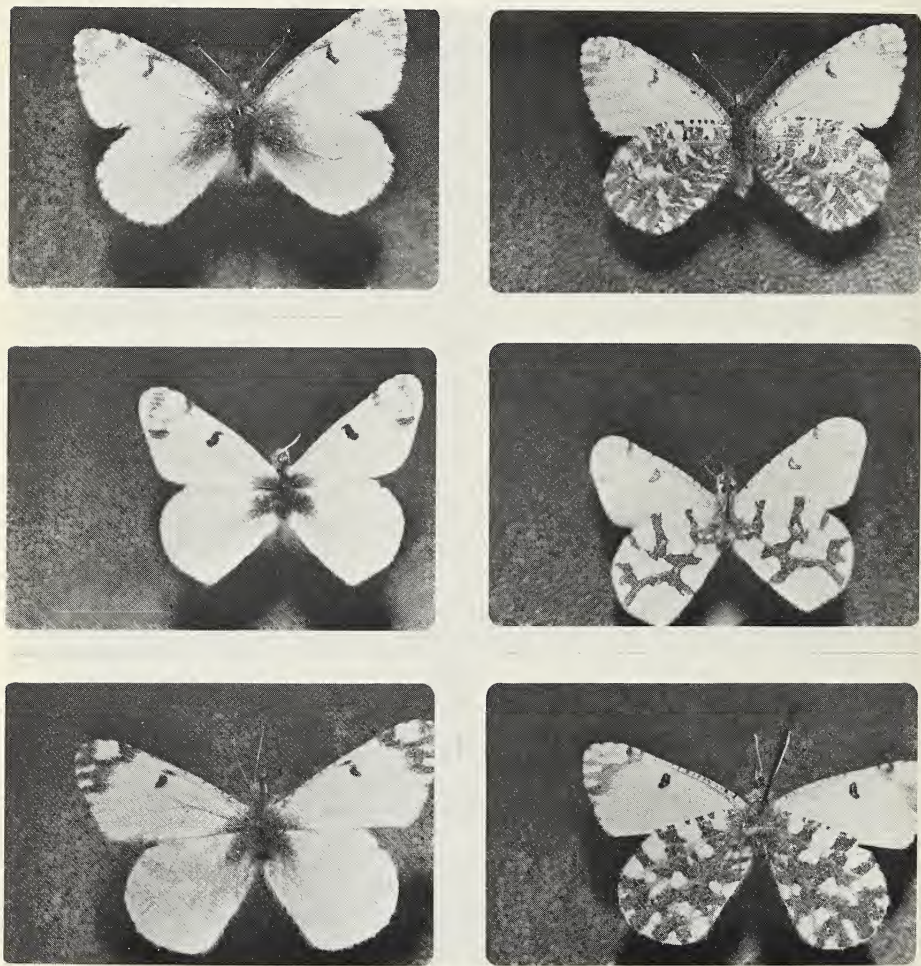


Fig. 1. Upper Row. Left: *Euphloe creusa*, male, upper surface; Right: *Euphloe creusa*, male lower surface; Middle Row. Left: *Euphloe olympia*, male, lower surface; Lower Row. Left: *E. ausonides*, male, upper surface; Right: *E. ausonides*, male, lower surface.

counted below the costal vein, as the bar is frequently ill-defined above this vein. Any white scale completely surrounded by black scales was considered as occurring within the bar. For individuals with more than fifty white scales in the bar, a portion of the bar was counted for the character, and the total was then arrived at by extrapolation.

The relative length of the radial veins were compared with the aid of an ocular grid. If one does not clear the wings, the veins are best observed on the ventral surface of the forewing with light from the illuminator striking the wing at an oblique angle.

Androconial scales were studied by scraping the area of the bar on the dorsal surface of the forewing with an insect pin or dissecting needle, transferring the scales to a microscope slide, covering them with a cover slip, searching for the proper scales under low power, and finally studying them under 200 to 400 power with a compound microscope. For permanent preparations, a mounting medium should be applied around the edge of the cover slip only, and pressure applied to the cover slip until the preparation dries.

GENITALIC PREPARATIONS. The genitalia were subjected to the usual preparatory procedures but were not mounted on slides. Genitalia were observed in a mixture of ethanol and glycerine in a small dissecting dish and were stored in small vials inside larger museum jars.

DRAWINGS. The subjects for the figures were observed through a binocular microscope equipped with an ocular grid. Pencil drawings were made on grid paper, and later the originals were traced onto finer grade paper and inked in.

MORPHOLOGICAL FEATURES

PIGMENTATION. It is well known that a group of pigmental compounds known as pterines is responsible for the white, yellow, and red wing colors of many members of the family Pieridae. Since these compounds have been demonstrated to occur in the wings of a species of *Anthocaris* by Good and Johnson (1949), and since the *Euchloe* possess white and yellow wing pigments, I decided to demonstrate the presence of pterines in the wings of *Euchloe*.¹ Specimens of *Euchloe ausonides* and *E. hyantis lotta*, as well as other species of Pieridae, were used in the experiment. Light blue fluorescent spots with RF

¹ Chromatography experiment conducted in insect physiology laboratory at San Jose State College, Dr. Ballard, instructor.



Fig. 2. Upper Row. Left: *Euchloe hyantis*, male, upper surface; Right: *E. hyantis*, male, lower surface; Middle Row. Left: *E. creusa*, male, right forewing; Right: *E. olympia*, male, right forewing; Lower Row. Left: *E. ausonides*, male, right forewing; Right: *E. hyantis*, male, right forewing.

values of 0.21 were obtained for both species of *Euchloe* with the propenol-ammonia solvent system. Since this finding was also produced with a wing sample of *Pieris rapae* L. it was tentatively assumed that leucopterin, the pigment responsible for the white wing color of many Pieridae, was the compound which formed these spots. Light blue fluorescent spots with RF values of 0.35 and barely discernable purple fluorescent spots with RF values of 0.29 were obtained for both species with the butanol-acetate-water solvent system. It was deduced that these values possibly represented breakdown products of xanthopterin, the pigment responsible for the yellow wing colors of many Pieridae. Needless to say, these results are far from definitive. It was realized that either larger samples or more refined techniques should be used in conjunction with chemically defined standards if significant differences are to be shown between species or populations of *Euchloe*.

The differences between species, populations, and individuals with regard to the whiteness of wing color may be due to the presence of varying proportions of xanthopterin mixed with leucopterin. The pearly lustre or sheen or its absence are best explained by physical effects, i.e., the presence of ridges on the scales, the angle of scale elevation from the point of attachment, thickness of scales.

SCALE TYPES. The "marbling" on the ventral surface of the hindwings is composed of two types of scales. The first type, which consists of the white and yellow scales, is of roughly rectangular outline with lobes or teeth on the distal margin. There appear to be differences in the number and outline of the lobes or teeth between different populations or entities of *Euchloe*. However, a satisfactory method of noting these differences was not arrived at in the course of this study. The black scales on the ventral surface of the hindwing, which together with the yellow scales give the visual effect of green "marbling", are ovoid in outline and are dentate on the distal margin with the exception of many individuals of *Euchloe ausonides coloradensis*. The distal margin of the black scales of these individuals is simple.

The males possess androconial scales on the dorsal surface of the forewings in the area of the black bar marking located at the distal margin of the discal cell. The location of these

TABLE 1. STATISTICAL SURVEY OF SOME WING CHARACTERS

	FOREWING ¹			BAR WIDTH ²			SCALE NUMBER ³		
	\bar{X}	$S_{\bar{X}}$	N	\bar{X}	$S_{\bar{X}}$	N	\bar{X}	$S_{\bar{X}}$	N
<u>Euchloe ausonides</u>	19.9	.12	158	11.7	.25	160	81.0	3.57	158
	20.4	.18	72	15.2	.46	62	52.8	6.50	58
<u>Euchloe a. coloradensis</u>	19.5	.03	35	10.8	.54	44	72.9	7.00	44
	18.7	.62	6	13.9	.81	8	50.6	7.22	8
<u>Euchloe a. mayi</u>	19.6	-	1	8.1	.67	10	103.0	20.03	10
	-	-	-	11.0	2.00	3	78.3	30.81	3
<u>Euchloe creusa</u>	17.4	.18	19	9.9	.64	18	9.9	1.86	18
	17.7	.36	5	10.5	1.35	4	1.5	1.06	2
<u>Euchloe hyantis</u>	17.7	1.80	39	12.9	.26	49	.2	.06	49
	18.8	.26	15	15.5	.65	15	.4	.13	16
<u>Euchloe hyantis lotta</u>	17.8	.15	83	20.4	.88	94	.1	.02	95
	17.9	.17	52	23.7	1.46	50	.2	.06	52
<u>Euchloe hyantis andrewsi</u>	18.5	.24	5	13.0	.60	8	6.0	1.99	8
	-	-	-	18.0	-	1	4.0	-	1

scales has never been reported for members of the tribe Euchloini. Warren (1961) and Chang (1963) have reported that the androconial scales have a distinctive shape which is constant for any given species of the genus *Pieris*. It was hoped that these scales would furnish similar diacritical differences in the Nearctic *Euchloe*, but upon microscopic examination they were found to show very slight interspecific differences. While the androconial scales of the *Ausonides* species group were relatively constant in having the lateral edges of the scales approximately parallel or slightly divergent, the androconial scales of the *Hyantis* complex were found to be quite variable. On more than one occasion scales varying from ovoid to trapezoidal were found on one specimen of *Euchloe hyantis lotta*.

BAR CHARACTERS. Since Brown (1955) reported that *Euchloe hyantis lotta* can be distinguished from *E. ausonides coloradensis* by its wider bar marking, it was decided early in the study to use this as a possible character in the study. The bar marking was measured by counting its width at a point near the middle in scale rows, i.e. the number of scales encountered in a line across the marking. All specimens recorded in the study were coded for this character. It was found that although individual variation was wide it did give a good measure of difference between certain entities (see Table 1).

In looking at specimens with intent to code for the above character, it was discovered that all specimens of *E. ausonides* possessed a scattering of white scales within the bar, while individuals of *E. hyantis* did not. Hence, the writer coded all specimens for the number of white scales in the bar marking. This character appears to be the best qualitative means of separating adults of *Euchloe ausonides* from *Euchloe hyantis* without resorting to dissection of the genitalia. Occasionally worn individuals of *E. ausonides*, especially females, will not display this character well as the scales appear to be more deciduous with age than are the other scales on the wings. Some populations of *Euchloe hyantis* that occur in the middle elevations of the Sierra Nevada of California are composed of individuals which so closely resemble *E. ausonides* from nearby areas that only by examining the individuals in question under a binocular microscope for this character can one be sure which species he is dealing with. The genitalia of such individuals subsequently support the conclusions which were arrived at on the basis of the presence or absence of white scales in the bar

marking. When other evidence, which will be presented in later papers of this series, indicates that *Euchloe hyantis* must have become isolated from the line which gave rise to the radiation of the *Ausonides* species group at a relatively early date, one must realize that this is either a startling example of convergent evolution or an improbable coincidence.

VENATION. In the past, several workers, including Dyar (1894) and Grote (1900), have proposed that members of the genus *Euchloe* can be discriminated on the basis of wing venation, while other writers such as Butler (1899) and Klots (1930a) have argued against the wisdom of employing this character. The radial veins on the forewing were usually used in attempts to utilize wing venation as a classificatory aid for *Euchloe*. The antagonists to such hypotheses reasoned that these characteristics were variable from one specimen to another. The present writer found that although the state of the radial veins varied slightly from one individual to another, definite trends for each species were clearly discernible. (see Fig. 4). The method employed was to contrast the length of the stem of the fourth and fifth radial veins from the bifurcation of the third radial with the length of the fourth radial vein. A trend for *Euchloe creusa* could not be noted owing to the small sample that was available, however specific characteristics were found for the other three species. The fourth radial of *Euchloe olympia* was invariably longer than its stem, the length of the fourth radial of *E. ausonides* was shorter or about equal to the length of its stem, and the fourth radial of individuals of *Euchloe hyantis* was always shorter than its stem. In fact, the fourth radial vein of both wings of many individuals of *E. hyantis* was found to be absent or only barely present.

EXTERNAL GENITALIA. An excellent world-wide tribal revision of the Euchiini by Klots (1930a) was based in large part on the structure of the external genitalia of the male insects. In spite of that fact, no satisfactory genitalic characteristics have been reported at the species level for any of the Nearctic *Euchloe*. As with many other characteristics of this subgenus, the external genitalia are perplexingly similar in superficial appearance. As a result of the study reported in this paper several features of the genitalia were found which will readily separate individuals of the two species groups involved. The outline of the juxta, when viewed from the posterior angle, is V-shaped for individuals of *Euchloe ausonides*

and is Y-shaped for the other three species (see Fig. 3). For species of the *Ausonides* group, the lateral edges of the tegumen, when viewed from the dorsal aspect, are parallel and do not converge until just prior to the point of juncture with the uncus, while for individuals of the *Hyantis* complex, the lateral edges of the tegumen are noticeably convergent distally or are irregular. The saccus of members of the *Ausonides* group tends to be regular in outline, while the saccus of individuals of the *Hyantis* complex is irregular in outline. The cucullus of members of the *Hyantis* complex terminates abruptly after the elaboration of the distal tooth, while the cucullus area of the valvae of members of the *Ausonides* group extends a short distance beyond the distal tooth (Fig. 3).

KEY TO THE ADULTS OF NEARCTIC *EUCHLOE*

1. Length of R_4 much less than length of stem R_4 , white ground on ventral surface of hindwing usually with pearly lustre, bar at end of cell on dorsal surface of forewing containing less than five white scales below costal vein, cucullus area of valvae terminating abruptly after distal tooth, lateral margins of uncus becoming convergent distally (dorsal view) *Euchloe hyantis* complex 7
- Length of R_4 about equal to or greater than length of stem R_4 , white ground on ventral surface of hindwing usually dull white, bar at end of cell on dorsal surface of forewing containing five or more white scales below costal vein, cucullus area of valvae not terminating abruptly after distal tooth, lateral margins of uncus parallel or only slightly convergent distally *Ausonides* species group 2
- 2(1). Juxta of male V-shaped, sterigma usually evenly curved in lateral or ventral view, female sometimes with dorsal surface of hindwing distinctly yellowish in color in comparison to ground of forewing .. 3
- Juxta of male Y-shaped, sterigma sinuous in lateral or ventral view, ground color of dorsal surface of hindwing almost never yellowish....6
- 3(2). Bar at end of cell on dorsal surface of forewing narrow, black scales on ventral surface of hindwing often ovoid in outline, a higher percentage of black scales as compared to yellow scales on ventral surface of hindwing, southern Rocky Mountains of northern New Mexico, Colorado, and southern Wyoming, often at high altitudes *Euchloe ausonides coloradensis*
- Bar at end of cell narrow or wide, black scales on ventral surface of hindwing with two or more teeth or lobes distally, black scales and yellow scales in about equal numbers on ventral surface of hindwing, not occurring in the areas listed above 4
- 4(3). Bar narrow, hindwing of female barely contrasting in color with forewing, low mountains of west-central Manitoba *Euchloe ausonides mayi*
- Bar wide, usually more than eleven scale rows in width, hindwing ground of female usually contrasting with that of dorsal surface of forewing, not occurring in west-central Manitoba. 5

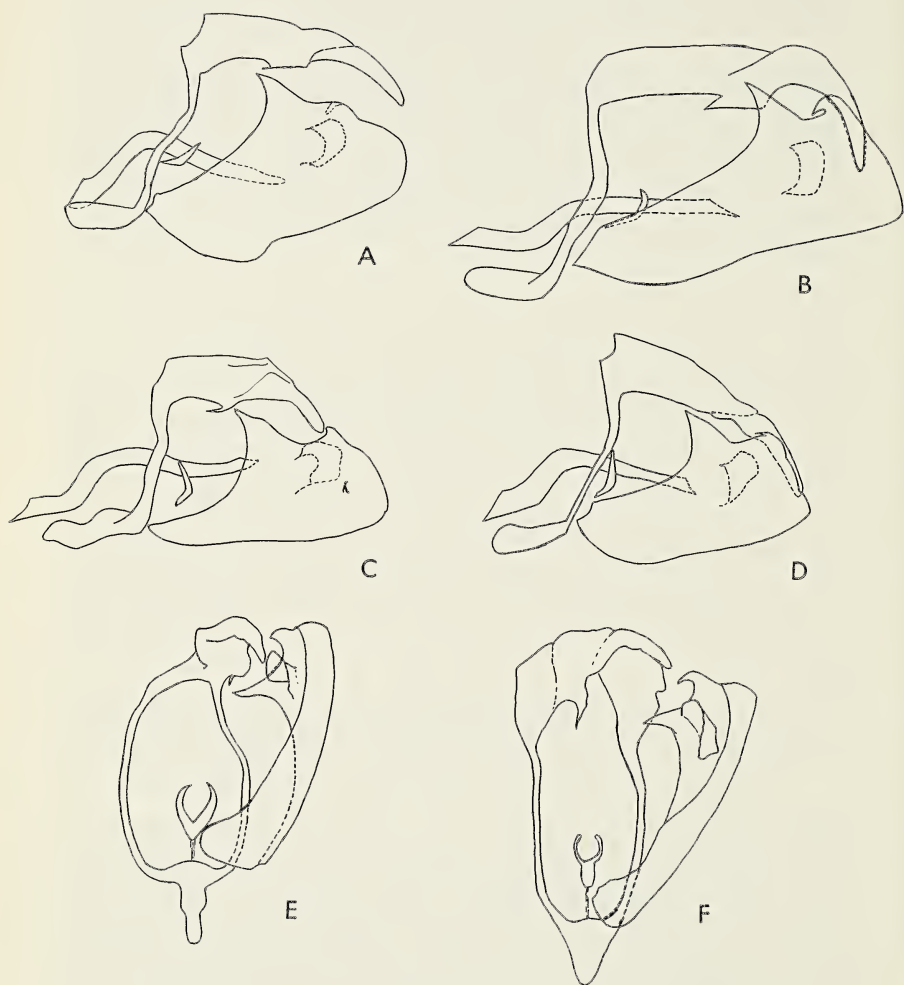


Fig. 3. Lateral view of male genitalia. A. *E. creusa*. B. *E. olympia*. C. *E. ausonides*. D. *E. hyantis*. E-F. Posterior view of male genitalia showing two configurations of juxta.

- 5(4). Female possessing one of three phenotypes, i.e. both wings white dorsally, both yellow, or forewing white and hindwing yellowish, occurring in the Coast Range, Sacramento Valley, and northern San Joaquin Valley in California from Mendocino County south to Monterey County *Euchloe ausonides ausonides*
 Female with dorsal surface of hindwing always distinctly yellowish, not in the lowlands of central California, southern Rocky Mountains, or west-central Manitoba *Euchloe ausonides* ssp.
- 6(2). Antennae clothed with white scales only, marbling on ventral surface of hindwing strongly reduced, black marking on apex of forewing often reduced, buff-colored scaling usually not present on costal margin of forewing, black scaling not invasive on dorsal surface of hindwing, occurring in eastern half of United States and adjacent portions of Canada in Manitoba and Ontario *Euchloe olympia*
 Antennae clothed with both white and black scales, marbling on ventral surface of hindwing often heavy and of a "broken" nature, black marking on apex of forewing not reduced, buff-colored scaling present on costal margin of forewing, black scaling at base of hindwing on dorsal surface invasive outwardly more so than other species or Nearctic *Euchloe*, occurrence associated with mountain cordillera of Canada and Alaska occurring near timberline, i.e. 7000' in southern Alberta, 4000' in northern British Columbia and close to sea level in Northwest Territories (McKenzie River delta) *Euchloe creusa*
- 7(1). Occurrence associated with Northern Desert Scrub (sagebrush) or Southern Desert Scrub Biomes (desert) west of the Continental Divide (except Rio Arriba County, New Mexico) and east of the Sierra Nevada and Cascade Mountains *Euchloe hyantis lotta*
 Occurrence in the north Coast Range of California, west slope of the Sierra Nevada, Transverse Ranges of southern California (excluding lower desert slopes), and the Peninsular Ranges of San Diego County, California and Baja California del Norte 8
- 8(7). Occurring in the north Coast Range of California from Sonoma County north to Siskiyou County *Euchloe hyantis hyantis*
 Not occurring in the north Coast Range of California 9
- 9(8). Occurring in the higher portions of the San Bernardino Mountains *Euchloe hyantis andrewsi*
 Not occurring in the higher portions of the San Bernardino Mountains of southern California *Euchloe hyantis* ssp.

Euchloe ausonides (Lucas)

Male. — Forewing length, 21 mm. Antennae: brownish-tan, outer surface of shaft clothed with black and white scales, black predominating, nudum and inner surface of shaft naked, tip of nudum with small microtrichia; labial palpi twice as long as head, directed anteriorly at a slight dorsal angle, clothed with black and white elongate scales, about three and a half times as long as wide, long white hair-like scales on inner face, similar black scales directed ventrally, a group of longer scales, both white and black, projecting from ventral base of palpi; head

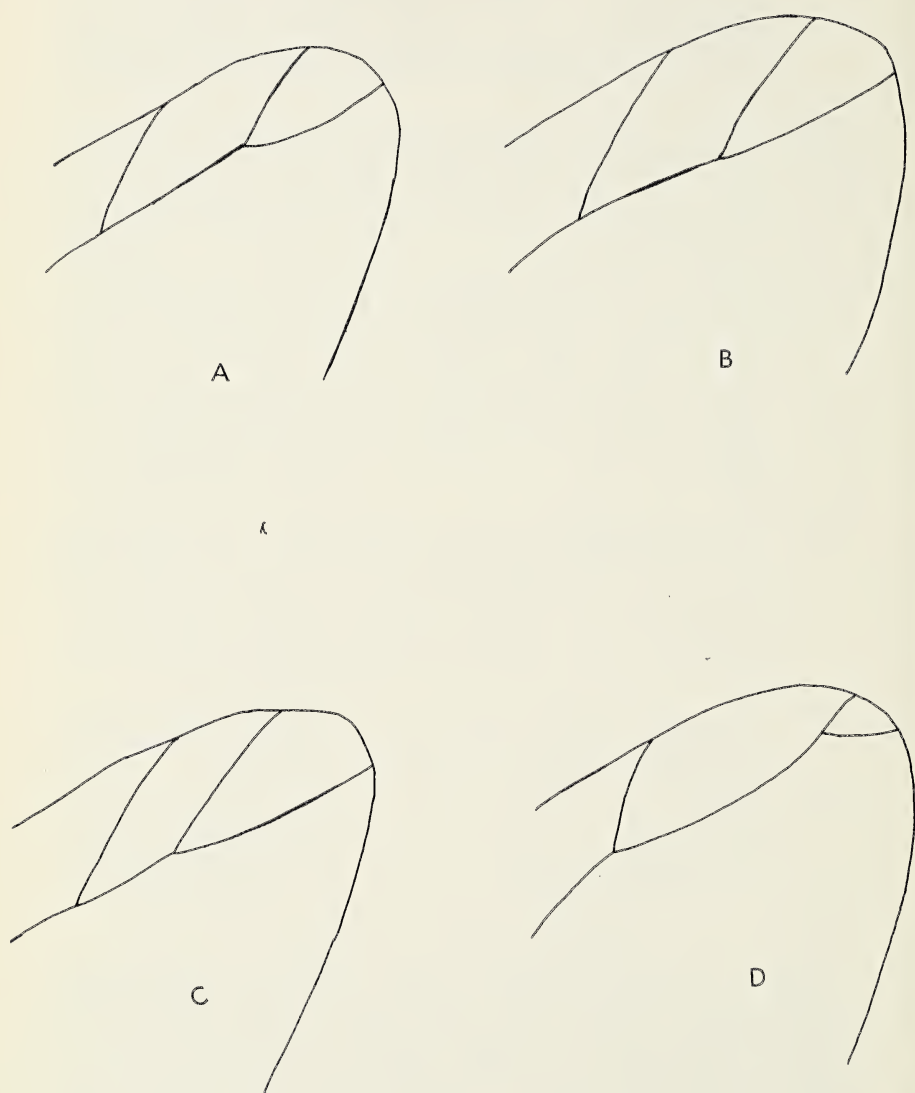


Fig. 4. Venational configuration of radial group of right forewing. A. *E. ausonides*. B. *E. creusa*. C. *E. olympia*. D. *E. hyantis*.

black with eyes green, frons with prominent tuft of long black, white, and yellowish hair-like scales, primarily white ventrally and yellowish laterally; vertex with long white hair-like scales, a patch of yellow and black hair-like scales half the length of those on center of vertex present on lateral margins of vertex, a group of shorter bright yellow scales between eyes and base of antennae; eyes bordered dorso-posteriorly by bright yellow and black flattened scales, a collar of bright yellow hair-like scales on cervical region adjacent to posterior and ventral margin of eyes.

Thorax: clothed with black appressed quadrate flattened scales and long hair-like scales, whitish-gray throughout 9/10 of length and black at base; pleuron covered with yellow sub-elliptic flattened scales and long yellowish hair-like scales; legs with femora covered with white flattened scales becoming tan distally, also with long white hair-like scales predominately on ventral surface and becoming shorter distally; tibia, tarsi and pretarsi brownish-tan, covered with stout setae, narrow white flattened scales on sparsely clothed tibia and tarsis. Wings: forewing with costal and outer margins slightly curved, inner margin straight, outer margin pointing outward anteriorly giving wings a slightly pointed look, stem R_4 longer than R_5 , upper surface completely clothed with flattened dull-white scales in approximate vertical rows except as follows: black flattened scales occurring solidly on basal one-tenth of wing, on costal margin of wing as eight small vertical marks extending to cell, on apex in typical *Euchloe* manner with intermixed white scales from R_1 to M_3 at distal ends of veins, and at distal end of discal cell as patch about thirteen scale rows wide with about one hundred white scales intermixed, long grayish-white hair-like scales coinciding with basal patch of black scales, yellow-buff narrow flattened scales extending along costal margin from base to apex, fringes (along inner and outer margins) composed of long white hair-like scales, black hair-like scales on fringe at terminus of R_5 , M_1 , M_2 , M_3 , and Cu_1 . Hindwing above with dull white scales as on forewing, black flattened scales on basal area of wing, extending outwardly further than on forewing, at stem of cubitus, and at terminus of all veins coinciding with long black hair-like scales on fringe; ventral surface of forewing with white scales as above, black scales as above on costal margin and outer margin, black patch at end of discal cell not as extensive as on upper surface and white scales absent, black scales absent at base of wing and

much less extensive on apical area, yellow-buff scales as on upper surface, sparsely distributed white hair-like scales occurring anterior to cubitus and extending to outer end of discal cell, flattened yellow scales occurring with black scales on apical area giving greenish appearance; lower surface of hindwing with flattened slightly dentate white scales in rough rows in between complex "green" marbled pattern produced by intermixing of flattened black and yellow scales, long hair-like scales, white on white areas and pale yellow over marbling extending from base of wing approximately to an imaginary line from distal end of anal margin to distal end of inner margin, a small patch of flattened black scales contiguous with marbling at Mu-Cu with one long black hair-like scale. Abdomen: dorsum clothed with flattened black scales intermixed with a few flattened white scales, white scales increasing and black scales decreasing ventrally until all white on sternum, long grayish hair-like scales on anterior half of abdomen and along entire length on sternum, white slightly spatulate scales sparsely covering posterior half of abdomen and densely covering posterior margin of segment eight and outer surface of valvae.

Female. — Forewing length, 22 mm. As in male except patch at end of discal cell of forewing about eighteen scale rows in width with about twenty white scales intermixed; hindwing above with scales yellow-cream in color; scales on lower surface of forewing largely buff in color, about fifty white scales in center of patch at end of FW discal cell ventrally.

Euchloe creusa (Doubleday)

Male. — Forewing length, 18 mm. Antennae brownish-tan, outer surface clothed with black and white scales, white predominating; hair-like scales on dorsal surface of thorax as in *E. ausonides* but denser, yellow flattened and long yellow hair-like scales on pleuron; legs with long black and white hair-like scales primarily on ventral surface of femora, white predominating; forewing with stem R_4 s about equal in length to R_5 , upper surface of forewing with eight black marks on costal margin, "Euchloe" mark at apex with white area above M_1 not as a well-defined circle, instead the effect is of a diagonal bar beginning between R_3 and R_4 and ending between M_2 and M_3 ; bar mark at distal end of cell about eight scale rows in width with about 35 white scales intermixed; flattened black scales extending into cell from basal area on dorsal surface of hindwing; white scales

on ventral surface of hindwing more iridescent than those of *E. ausonides*; marbling more extensive and irregular than that of other Nearctic species. Abdomen: flattened black scales on dorsal and pleural areas with only an occasional white scale; venter covered with a mixture of white and pale yellow flattened scales; long hair-like scales covering entire surface of abdomen, gray on dorsal and pleural areas, yellowish ventrally.

Female. — Forewing length, 17.8 mm. As in male except patch at end of discal cell on forewing about sixteen scale rows in width with about seven white scales intermixed; flattened black scales on upper surface of hindwing as in male but some present on all areas of wing; a small patch of about 30 black scales present on ldc; about 25 dull gray scales in center of patch at end of discal cell on ventral surface of forewing.

Euchloe olympia (Edwards)

Male. — Forewing length, 18.5 mm. Antennae: outer surface of shaft and most of club clothed with small white flattened scales; labial palpi about one and a half times as long as head, clothed with white elongate scales, about four times as long as wide, long white hair-like scales projecting downward and inward, a few long black hair-like scales intermixed on outer face; frons with prominent tuft of long white and black hair-like scales directed anterad slightly beyond tips of palpi, white mesially with some black scales laterally; pleuron covered with yellow sub-elliptic flattened scales and long yellow hair-like scales; legs with scaling as for *E. ausonides*. Wings: R_5 almost twice length of stem R_4 , upper surface with white ground slightly more iridescent than that of *E. ausonides*; black maculation on apex reduced to three small patches, one just basal to R_3 bifurcation, one at distal end of M_3 , and one composed of scattered black scales near R_4 ; four small vertical marks in C-Sc formed by small patches of black scales; patch at distal end of discal cell on dorsal surface of forewing about 13 scale rows in width with about five white scales intermixed; black scales not present in fringe; buff scales absent from costal area; hindwing with long black scales in fringe at termini of R_s and M_1 ; ventral surface of forewing with black scales as above patch at R_4 absent, flattened yellow scales occurring with black scales in two apical patches giving greenish appearance; patch at end of discal cell much less extensive than on dorsal surface with about 100 white scales in central portion; ventral surface of hind-

wing with marbling pattern strongly reduced. Abdomen: dorsal and pleural areas clothed with flattened black scales with a few white scales, venter clothed with white scales.

Female. — Forewing length, 19.2 mm. As in male except patch at end of discal cell on forewing about 14 scale rows in width with no white scales intermixed; about 50 white scales in central portion of patch at distal end of cell on ventral surface of forewing.

Euchloe hyantis (Edwards)

Male. — Forewing length, 17.5 mm. Outer surface of antennal shaft and club clothed with white and black scales, white predominating; labial palpi lacking black elongate scales as in *E. ausonides*, frons lacking long yellowish hair-like scales; patch of hair-like scales at lateral margin of vertex with white and black scales; a group of short pure white scales between eyes and base of antenna; on forewing stem $R_4 + 5$ much longer than R_5 ; patch at distal end of discal cell on dorsal surface of forewing about 13 scale rows in width with only two white scales intermixed; buff scales absent from costal margin; ventral surface of forewing with patch at distal end of cell about as extensive as on dorsal surface with no perceptibly lighter scales in center.

Female. — Forewing length, 18.1 mm. As in male except patch at distal end of cell on dorsal surface of forewing about 16 scale rows in width with no white scales intermixed; about 70 light gray scales in center of patch at end of FW discal cell ventrally.

ADDENDUM

After the manuscript for this paper was submitted for publication, the material of this genus contained in the Canadian National Collection was examined. Since the material there included important distributional additions, the data for their material from Alaska and Canada are presented below. It should be noted that none of this information has been incorporated on the distribution maps.

LABORATORY PRODUCTION OF THE MONARCH BUTTERFLY, *Danaus plexippus*

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Department of Biology, Whittier College, Whittier, California

THERE IS NEED for monarch butterflies, *Danaus plexippus* (Linn.), for scientific and educational work. For these purposes equipment and methods for rearing the butterfly are being developed.

In the field, in regions where the monarch occurs, in season, the butterfly is attracted to milkweeds for egg-laying. Plantings of *Asclepias curassavica* are especially useful for luring migrating butterflies to obtain them for experimental work. This plant is perennial and sub-tropical. In addition to milkweed flowers, the butterflies are attracted to many other kinds of flowers for their nectar.

In the laboratory the butterflies will drink from damp paper, water, and water to which honey has been added. Honey was added to the water at the rate of 1 teaspoon per cup of water. Crumpled paper toweling of a stiff variety or newspaper was placed in a shallow dish containing the solution. The butterflies would stand on, and drink from the damp paper.

Oviposition cage. An essential tool for rearing the butterfly is the oviposition cage. The cage used by the authors (Fig. 1) is 17 inches tall, 20½ inches wide, and 12 inches deep. The bottom is ½ inch plywood to which a wooden frame is attached. One side is provided with a terry cloth sleeve 6 inches in diameter and 10 inches long attached to wooden panel. Through this sleeve, butterflies, glass tumblers with water, cuttings of milkweed plants, and cut flowers can be passed without danger of butterflies escaping. The top, back, and one side of the cage are covered with muslin. The cloth at the back is in the form of a curtain, fastened at the top and weighted at the bottom with a piece of masonite ¼ by 3 by 20 inches. The masonite is held against the back of the cage by sheet-metal guides. The front of the cage is covered with glass or plexiglas.

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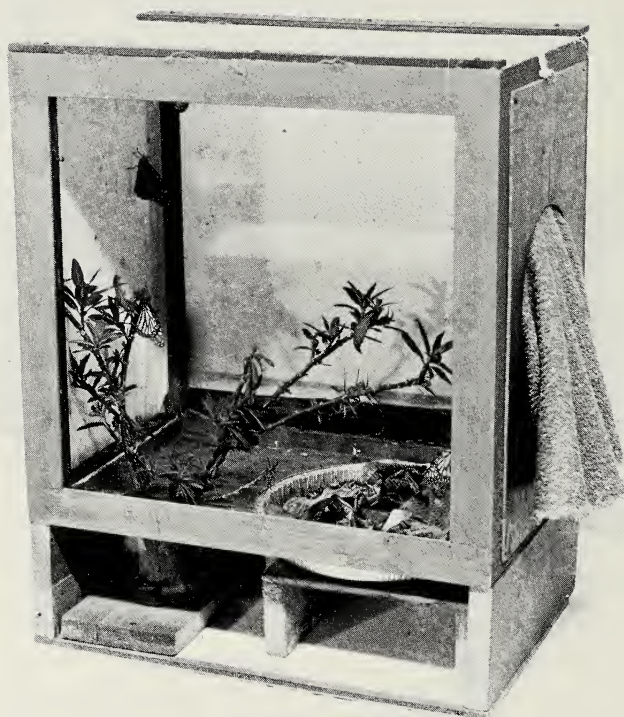


Fig. 1.—Oviposition cage.

When in operation, the cage contains a 9 by 1½ inch aluminum cake pan with honey-water and crumbled paper, a glass tumbler containing water and cuttings of milkweed, *A. currassavica*, and a number of egg-laying females.

Under the artificial conditions of the oviposition cage the butterflies will not always mate when they become mature. It is usually necessary to force-mate the butterflies by a method used by the workers at the University of Toronto, Canada, (Urquhart 1965).

Incubation of eggs. Eggs are laid almost exclusively on the leaves and stems of milkweed. Occasionally some eggs are laid on the damp paper, on the tumbler, or on the wood frame of the cage. The milkweeds are replaced with fresh plants every 1 to 3 days. Small parts of leaves and stems bearing 1 or several eggs are cut from the plants, placed in a pile on a piece of glass 4½ inches square, and covered for incubation with a clear, plastic cup 3½ inches in diameter and 3 inches tall (Fig. 2). A disposable cup of this size is obtainable from most retail liquor stores. Any number of eggs up to 100 may be incubated at one time under a cup. Humidity must be kept low enough to prevent the growth of mold, which seems to kill the eggs.

Rearing the caterpillars. When the eggs hatch, most of the larvae crawl up on the sides of the cup, now a cage, and rest for a time before they are ready to feed. At this time 1 or 2 milkweed terminals composed of 4 to 6 leaves each are placed in the cage, partly in contact with the plastic surface. Before long the caterpillars transfer to the milkweed and commence to feed. As the caterpillars grow and become crowded they are distributed among other cages. Three fifth instar caterpillars can be reared to maturity in 1 cage if they are of slightly different ages so that they do not interfere with each other when they are preparing to suspend themselves.

Storage of pupae. Pupae can be held in the cage until the butterflies emerge, or they can be removed and stored on a string rack. This rack is a wood frame with strings stretched horizontally 4 inches apart. A cardboard tray beneath the strings is used to collect tachinid parasites issuing from suspended insects. Parasites may be present in larvae collected in the field, but not in laboratory-reared material.

The silk to which the pupae are attached will peel off the plastic surface if it is first started by rubbing with the finger or a rubber eraser. A mounting device is made of a 1½-inch long piece of ¾-inch masking tape. First, fold the masking tape at



Fig. 2.—Plastic cup cage for incubating eggs and rearing small caterpillars.

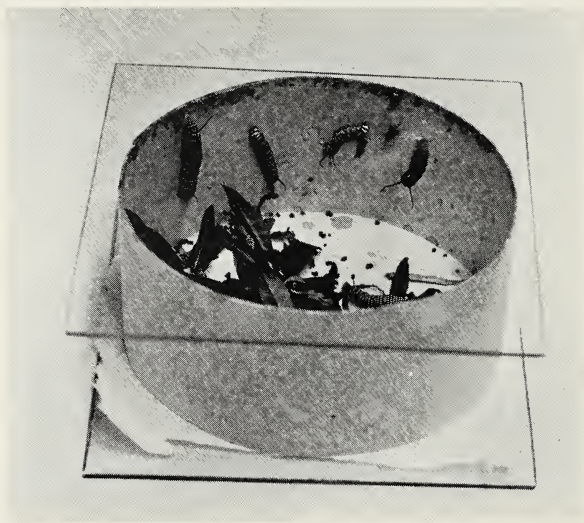


Fig. 3.—Cardboard cylinder rearing cage.

one end, lengthwise, half way. Then, place the silk of the pupa on the other end and press the adhesive surfaces together with the silk between. The pupa can then be fastened to the string by a slanting cut in the folded tape or by folding $\frac{1}{4}$ -inch of the tape over the string and securing it with a small paper clip. The pupa can then be identified by marking a number on the masking tape.

Cardboard rearing cage: A cage for rearing a larger number of fifth instar caterpillars to maturity per cage is composed of a cardboard cylinder 6 inches in diameter and 3 inches tall (Fig. 3). The top is a 7-inch square piece of glass or plexiglas. A 7-inch square piece of paper is laid on the bottom glass to absorb moisture and to keep the glass clean. The capacity of this cage is about 15 insects. When the caterpillars finish feeding, they crawl to the cover, form the silk button, and suspend themselves. Pupae suspended in this manner can be stored in a slotted wooden rack (Fig. 4). If desired, the pupae can be removed from the glass cover, either by scraping the silk off with a razor blade, or peeling it off wet. The insects can then be fastened to masking tape as described earlier. The removal of pupae from plexiglas is simpler. The silk peels off easily, dry.

It is more efficient to rear the larger number of caterpillars at one time, particularly if there is no virus disease (Urquhart, 1966 and Urquhart and Stegner, 1966) present. An advantage in rearing the smaller number of caterpillars in one cage is that if one insect is infected with the virus disease common to the monarch butterfly, only 2 additional specimens are exposed. Also, the plastic cages are more easily sterilized without damage to them.

The caterpillars were reared in a dry, well-ventilated basement room with daylight, at about 74 degrees F. Under conditions of high humidity the silk may not adhere well to the plastic, but it never fails to stick to the glass.

Egg-production. An egg-production experiment was carried out in the Whittier College greenhouse from May 15 to June 27, 1968. The object of the experiment was to determine the egg-laying potential and longevity of butterflies which were fed on honey-water and flowers, and on honey-water alone. The frequency with which the butterflies feed on flowers in the field suggests that flowers might be necessary for the greatest egg-production in a cage.

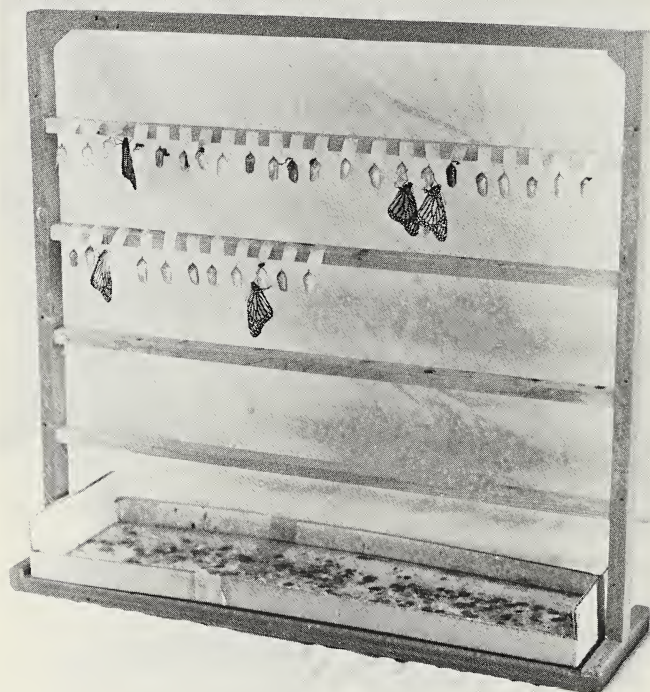


Fig. 4.—Wooden rack for storing and displaying suspended pupae.

The greenhouse is partially shaded by eucalyptus trees. The top ventilator was open continuously. Maximum and minimum temperatures F. were read on 26 and 25 days, respectively of the 43 days of the experiment. The maximum, minimum, and average temperatures for the maximum temperatures were 95, 74, and 82.2 degrees. The maximum, minimum, and average temperatures of the minimum temperatures were 67, 54, and 56.8 degrees.

The butterflies used in the experiment were reared from eggs which had been laid by a number of laboratory-reared butterflies.

TABLE 1. DATES BUTTERFLIES WERE MATED AND INTRODUCED
INTO OVIPOSITION TEST CAGES.

Butterfly number	Date emerged	Date mated	Date transferred to cage	
			Honey-water and flowers	Honey-water alone
1	May 10	May 16	May 15	
2	May 10	May 16		May 15
3	May 17	May 22	May 22	
4	May 17	May 22		May 22
5	May 18	May 23	May 23	
6	May 18	May 23		May 23
7	May 19	May 25	May 25	
8	May 19	May 25		May 25

TABLE 2. LONGEVITY AND EGG-PRODUCTION OF 8 BUTTERFLIES, 4 FED ON
HONEY-WATER AND FLOWERS, AND 4 FED ON HONEY-WATER ALONE.

CONDITION

<u>Honey-water and flowers</u>			<u>Honey-water alone</u>		
Longevity		Total eggs	Longevity		Total eggs
Butterfly	Days		Butterfly	Days	
1	41		2	34	
3	37		4	40	
5	36		6	44	
7	35	1551	8	44	2365
Ave.	37.1	387.8		40.5	591.3

Procedure. Two oviposition cages were used with 4 force-mated butterflies distributed to each cage as shown in Table 1. Each cage contained honey-water and milkweed leaves. One cage contained, in addition, a separate tumbler with fresh-cut flowers—scabiosa, lantana, orange, milkweed, and other flowers. The flowers were attractive to the butterflies, and they were observed to feed on them frequently. The milkweed leaves, upon which the eggs were laid, were replaced with fresh leaves at from 1 to 3-day intervals, and the eggs counted. Tagged butterflies were used in the experiment. The longevity of each butterfly, therefore, was measurable, but it was not possible to determine the egg-production of the individual butterfly.

Results. The results of the experiment are shown in Table 2. The butterflies in the cage without the flowers laid 60.8 percent of all the eggs, an average of 591.3 eggs per butterfly. These butterflies lived an average of 40.5 days, 3.4 days longer than those with the flowers.

It is clear, contrary to what might be expected, that the flowers added nothing to the egg-laying ability of the butterflies. On the contrary, the flowers seemed to detract from the capacity of the butterflies to lay. A possible explanation of this result, suggested by Dr. Hovanitz, may be that time spent on the milkweed leaves may have been reduced by the attraction of the flowers. From a practical standpoint, it is convenient that flowers do not seem to be an advantage in egg-production.

The number of eggs laid by the butterflies with flowers was about equal to what Urquhart (1960) suggested might be expected to be laid under ideal conditions. He examined monarch ovaries and found more than 400 eggs.

Note: Seeds of *Asclepias curassavica* are available from Clyde Robin, P. O. Box 2091, Castro Valley, California, and from Pearce Seeds and Plants, Moorestown, New Jersey 08057.

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OBSERVATIONS AND NOTES ON
THE REARING OF *PAPILIO INDRA*
KAIBABENSIS (PAPILIONIDAE)

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ON 31 MAY 1970 FIVE LARVAE of *Papilio indra kaibabensis* Bauer were found by the author on individual host plants of *Pteryxia petraea* (Jones) Coult. & Rose growing on the slopes and along the North Kaibab Trail opposite Roaring Springs, North Rim, Grand Canyon National Park, Arizona. These were taken back to Phoenix on 1 June 1970 along with a small amount of host plant material in an attempt at rearing. No previous attempt at rearing the larvae of this choice swallowtail had been made by the author.

The larvae found ranged as follows: one first-instar, one second-instar and three third-instars. These were numbered 1 through 5 respectively, to facilitate recording of individual behavior during the rearing process. Upon arrival at Phoenix it was discovered that larva No. 5 had moulted sometime during the several hours' return drive.

The larvae were kept indoors at a constant 80° F. and fed on the leaves of the host plant for five days, to 6 June 1970, during which time the host plant, in a vase of water, dehydrated and became stiff and brittle. By this time four of the five larvae had moulted and there were now one first-instar, one third-instar, two fourth-instars and one fifth-instar. It was immediately apparent that successful continuation of the rearing was dependent upon the acceptance by the larvae of substitute host plant. Emmel and Emmel (1967) found *Tauschia arguta* (T. & G.) to be an acceptable substitute and successfully reared *kaibabensis* larvae to maturity on it. This plant was not available to the author. It may have been possible to secure additional *Pteryxia* plants which also grow on the slopes at the South Rim of the Grand Canyon but, in view of the distance and time involved,

it was determined expedient to induce the larvae to accept still another member of the *Umbelliferae* as a substitute host.

An attempt to reconstitute half of the remaining *Pteryxia* plants by soaking in water for several hours was not successful. The remains of the other half of the original host were then placed in a small cooking pan holding approximately one pint of water, which was then heated and brought to a boil and then allowed to simmer for five minutes. The resulting solution was then poured into glass jelly jars, capped and allowed to cool. After cooling, this solution was used to water individual potted plants of young (less than one foot high) Fennel (*Foeniculum vulgare*). The watering was maintained on an hourly basis for several hours, during which time the larvae were allowed to find what little nourishment and moisture remained in the first remaining half of the original host. The third-instar, No. 2, and the two fourth-instar larvae, Nos. 3 and 4, moulted unobserved prior to inspection on the morning of the seventh.

In the early morning of 7 June 1970 each larva was transferred to its individual potted Fennel plant in the hope of obtaining acceptance. Larva No. 1 immediately accepted the substitute host and fed periodically until the afternoon of the eighth. Toward the end of that day it ceased feeding and remained head downward on a petiole. It was determined that this larva was preparing to moult.

The other larvae did not readily accept the Fennel and crawled restlessly over the soil in the pots. Cut sprigs of fresh, tender Fennel were then placed on the soil in each pot where the larvae crawled, as it observed that the larvae experienced great difficulty in attempting to crawl up the Fennel stems. Even with this method the larvae nibbled but briefly on the Fennel tips, which apparently did not completely satisfy their dietary requirements, and continued their restless movements. The feathery growth of the Fennel appeared to hamper the crawling progress of the larvae and they continually lost footholds and rolled over on their sides and backs.

On the morning of 8 June 1970 larvae Nos. 2, 3, 4 and 5 were removed from the pots and placed in individual empty one pound coffee cans. On the inside bottom of each can a cut-to-fit disk of household papered towelling had been placed and on this fresh sprigs of Fennel were laid. These sprigs were at first obtained from the plants which had been watered with the solution. The cans were then capped with the standard plastic

lid that comes with each can and placed on a window sill away from direct sunlight. This technique resulted in high humidities inside the rearing cans but also served to prolong the freshness of the foodplant. As the Fennel wilted in the course of time it became necessary to replenish the rearing cans with fresh material. This was done periodically during the day and on into the evening hours. Each can was also emptied of accumulated frass and a clean paper towel disk inserted. About 7:00 P.M. (M.S.T.) of the same day larva No. 4 began to feed earnestly on the Fennel and continued for approximately twenty minutes. This was in marked contrast with the earlier behavior which exhibited rejection of the substitute host after several nibbles. The two other fifth-instar larvae continued to maintain their restlessness, pausing only occasionally to nibble, then resuming their crawling. The fourth-instar larva, No. 2, remained quiescent and moulted unobserved early on the morning of the ninth.

On the morning of 9 June 1970 a review of the rearing cans revealed that, of the three later fifth-instar larvae, No. 5 remained motionless on its side on the bottom of the can in the characteristic attitude assumed by *Papilio* larvae prior to pupation. This was confirmed by examination of the larva through whose skin pupal features were distinguishable. It was noted that this larva failed to spin the silken button and girdle so characteristic of pupating larvae of this family. This may have been due to the smooth metal side of the rearing can which afforded little foothold for the larva. No difficulties were experienced, however, with similar rearing conditions for larvae of *Papilio cresphontes cresphontes* Cramer, which simply spun silken mats up a can's side to their pupation sites. Of the other two larvae, No. 4 continued feeding and No. 3 continued its virtually ceaseless crawling. A stiff sheet of paper placed vertically in the latter's can did not elicit a response toward selection of a pupation site and was ignored. The newly-moulted fifth-instar larva, No. 2, accepted the Fennel and fed eagerly after its mouthparts were sufficiently hardened. Larva No. 1 continued to feed for a time after moulting but then contracted an undetermined ailment, evidenced by an expelling of a greenish liquid from the mouth and excretion of a liquid frass. This larva rapidly lost the ability to maintain a grip on the substitute host, dropping to the soil and expiring shortly thereafter.

Larva No. 5 which had been determined to be prepupal was placed in an upright tube of rolled stationery paper of slightly

longer length. On the morning of 10 June 1970 an examination revealed that this larva had transformed to a chrysalis of slightly smaller proportions (Emmel & Emmel, 1967), measuring 24 mm. long by 8 mm. wide. This may have been brought about by a reduced intake of nourishment in the last larval instar.

It was of interest to note that, with the exception of the expired No. 1 larva, the other larvae experienced great difficulty in maintaining footholds and equilibrium on the Fennel sprigs. This was not the case with larvae of *Papilio zelicaon* Lucas which the author has successfully reared on Fennel under similar rearing conditions. Also of interest was the habit of *kaibabensis* larvae of remaining quiescent for long periods of time, on the order of a couple hours' duration or more between feedings in several instances, yet larval growth appeared to be rapid. Feeding was noted to be avid in all stages, both on *Pteryxia* and Fennel. Some difficulty was experienced by the larvae feeding on the Fennel sprigs as the long, thin filaments continually slipped past their grip. A preference was shown for feeding to begin at the terminal portion of each filament, though in some instances the larvae would nip off the filaments mid-way and feed upon the cut-off portions by holding these with their true legs. After the larvae had fed several times upon the Fennel sprigs from the plants watered with the solution, they were given fresh sprigs from untreated plants. These were accepted without hesitation. From then on only sprigs from untreated plants were offered to the larvae.

At 10:09 P.M. (M.S.T.) larva No. 3, which had previously exhibited the most reluctance to feed, accepted the Fennel and proceeded to feed avidly for approximately 10 minutes, whereupon feeding terminated and did not resume again. Symptoms of the ailment noted with larva No. 1 were exhibited by this larva at 6:15 P.M. (M.S.T.) on 11 June 1970. The larva gradually lost mobility and slowly shrank in size during the next several hours. However expiration, which appeared to be caused by a combination of starvation and dehydration, did not occur until 12 June 1970, probably due in part to the larger size of this larva. At 7:30 A.M. (M.S.T.) of that day larva No. 4 also excreted a voluminous liquid frass but did not exhibit the fatal symptoms previously noted in the other larvae. Instead it proceeded to fashion a silken mat on the side of the rearing can prior to assuming the pupation position and at 9:45 P.M. (M.S.T.) it slipped into the silken girdle. Pupation took place

unobserved during the early morning hours of the fourteenth. This chrysalis measured 29 mm. long by 9 mm. wide.

Larva No. 2 continued to feed on the Fennel until 15 June 1970. Prior to selecting a pupation site, in this case on the screen cover which replaced the plastic lid when the larva ceased feeding, this larva, too, excreted a voluminous liquid frass and soiled the paper towel disk extensively. It is not known at this time whether defecation of a liquid frass at larval maturity is the rule with this species or is caused by feeding on Fennel. This larva pupated at 11:30 P.M. (M.S.T.) on 16 June 1970 and a perfect adult female eclosed prior to sunrise on 28 June 1970.

However, the chrysalis of larva No. 4, which had developed to the verge of eclosion, died of unknown causes on 26 June 1970. At the time of this writing, 28 June 1970, the chrysalis produced by larva No. 5, though still viable, shows no signs of development and may have entered diapause.

It is interesting to speculate on the possibility of selective breeding utilizing larger numbers of larva in order to develop Fennel feeding populations. Since Fennel is easily grown from seed, such host acceptance would offer wider study by serious workers of the biology of this member of the *indra* complex. The small sample combined with high mortality did not permit the author to pursue this facet of his rearings.

ACKNOWLEDGMENT

The author would like to thank Dr. Frank F. Hasbrouck, Associate Professor of Zoology and Curator of Insects, Arizona State University, for critically reviewing the manuscript.

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POSTSCRIPT

The chrysalis produced by larva No. 5 on 10 June 1970, which indeed had entered diapause, eclosed a perfect female at dawn on 25 September 1970. Diapause was terminated by refrigerating the chrysalis for thirty days, from August 4 to September 4, then removing from refrigeration and maintaining at room temperature until eclosion. During the period prior to eclosion humidity was provided by placing the paper cylinder containing the chrysalis on a water-moistened paper towel.

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HABITAT — *Colias philodice eriphyle* and *Colias eurytheme*

W. HOVANITZ

These two species of *Colias* co-inhabit certain locales ranging from the Sierra Nevada of California to the Atlantic Ocean. Where the habitats coincide, there is extensive hybridization of the two mutually fertile species. The locality shown here is the Round Valley of Inyo and Mono counties, California, at an elevation of about 4,000 feet, late June, 1970. In the background are the White Mountains, directly north, with White Mtn. peak at about 14,500 feet. This is the most southern locality known for *C. philodice* in California though in the past (1920s) it was known as far south as Olancha.



EUPHYES DUKESI AND OTHER ILLINOIS HESPERIIDAE

RODERICK R. IRWIN¹

24 East 99th Place, Chicago, Illinois

FOR THE PAST SEVERAL YEARS, Dr. John C. Downey and I have been engaged in a survey of the butterflies of Illinois, which is expected to lead to the publication of an annotated checklist of the butterflies of that state. During the course of this study, numerous interesting records of HesperIIDae have been obtained, some of which I believe justify publication separately and in advance of the larger work, since they represent significant range extensions of the species involved.

Euphyes dukesi (Lindsey). Of perhaps the greatest interest and importance has been the fact that this intensely local skipper is apparently established in southern Illinois. Previously published records were summarized by Mather (1963; 1966). Price and Shull (1969) have recently published the first record of *dukesi* from Indiana. A specimen from Blackwater, Prince Albert County, Virginia, VI-13-64, leg. John Bauer, in the Carnegie Museum collection, represents an apparently previously unpublished Virginia record.

A single male of this species is in the collection of the Illinois Natural History Survey, Urbana, Illinois. It was taken at Karnak, Pulaski County, in extreme southern Illinois, on September 2, 1924, by T. H. Frison. In addition to the data label, this specimen bears a label reading "Upper side like / Type - Atrytone / dukesi / Lind. / underside / more contrasting / Det / B[arnes]. & B[enjamin]." This appears to have been the first record of the species following its original description, and consequently the earliest record from other than the type locality. Its existence has apparently remained unpublished until the present.

Downey took another male *dukesi* in the Pine Hills region of Union County, in southern Illinois, on September 10, 1966. Mr. H. A. Freeman kindly confirmed my identification of this specimen, which is much darker on the upper side than any other *dukesi* I have seen. It is almost wholly black, with only the faintest traces of fulvous basally on the fore wings and discally on the secondaries.

¹Honorary Curator of Lepidoptera, Illinois State Museum.

I took a rather worn male and a perfect female *dukesi* between 4:15 and 4:45 P.M. on August 31, 1969, in the same area where Downey found the species in 1966. The insects were found in an opening near the edge of a deciduous forest, just south of a road paralleling the south side of the Big Muddy River, about a half mile east of Illinois highway 3. The ground at this point was entirely dry, but there were extensive swamps just east of the area. No additional individuals of the species were seen; they may have been more plentiful within the swamp proper, but the lateness of the hour prevented a search for them there. This appears to have been one of the few reported instances of the capture of *dukesi* on dry ground, and is of particular interest since Mather (1963) indicates that the butterfly seldom strays from its marsh habitat.

Collecting by Downey and his associates in the Pine Hills and Lusk Creek (Pope County) regions of southern Illinois, as well as examination of museum collections, has revealed the presence of other Hesperiidæ which had not been expected to occur in Illinois. Among these are three species of *Amblyscirtes* which to my knowledge have not previously been recorded from so far north in the Mississippi Valley.

Amblyscirtes carolina Skinner. Two specimens from the Pine Hills, Union County, September 1, 1966, leg. J. C. Downey. The range of this species is given by Klots (1951) as "Georgia to Virginia" and it was unreported from any other area until Mather and Mather (1958) published a Mississippi record. This record from Illinois represents a further range extension. Identification of this and the following species was confirmed by Freeman.

A. aesculapius (Fabr.). Specimens from Pine Hills, Union County, August 21, August 25 and September 1, 1966, leg. J. C. Downey, and from Lusk Creek near Eddyville, Pope County, July 7, August 9 and August 30, 1967, leg. J. C. Downey.

A. linda H. A. Freeman. I found a specimen which appeared to be *linda* in the series of *A. belli* H. A. Freeman in the collection of the Field Museum of Natural History. It was taken at Makanda, Jackson County, on July 8, 1896, by A. J. Snyder. I sent it to Freeman, who confirmed my identification. Like the two preceding species, this is the northernmost record of *linda* known to me.

A. belli H. A. Freeman. This species was itself taken by Downey at the Lusk Creek locality near Eddyville, Pope County, August 9, 1967, 1 ♂ 1 ♀. This species has previously been

recorded from St. Louis County, Missouri (Remington, 1956). These specimens were also determined by Freeman.

Autochton cellus (Bdv. & Lec.). This scarce and local species was taken in the Pine Hills region on July 26, August 21 and September 1, 1966 (collector not indicated).

Hesperia ottoë Edw. Nielsen (1958; 1960) described the discovery of this species in Michigan, and stated that this represented its first reported occurrence east of the Great Plains. The wide gap between these two areas is partially bridged by the finding of *ottoë* in Illinois. A female of this species was taken by Alex K. Wyatt at Waukegan, Lake County, on July 28, 1946. Thomas Taylor has taken a number of specimens at Mason State Forest, Mason County, on the following dates: July 19, 1963, 1 ♀; July 11, 1964, 1 ♀; and July 19, 1964, 8 ♂ 3 ♀. The first-named specimen was examined by H. A. Freeman, who confirmed its identity. The others agree with it exactly. It may perhaps be significant that the record from Waukegan was six years earlier than the first Michigan record given by Nielsen.

The preceding species discussed have not previously been recorded from Illinois. The two following have been; but additional comment on their occurrence in that state may be worthwhile here.

Problema byssus (Edw.). The first record of *byssus* from Illinois was given by Remington (1956) from Elsah, Jersey County. Since then it has been found at five other locations in the state. They are Peoria, Peoria County; Mason State Forest, Mason County; Streator, La Salle County; Valmeyer, Monroe County, and Perryton Township, Mercer County. Complete data of capture will be given in the "Butterflies of Illinois," in preparation. It is interesting and perhaps significant that all these localities lie at no great distance from either the Illinois or Mississippi Rivers.

Thymelicus lineola (Ochs.). Since the publication of my paper on this adventive European species in Illinois (Irwin, 1968), only a single additional record of the skipper from outside the Chicago metropolitan area has been reported: Divine, Goose Lake Township, Grundy County, VI-22-68, leg. P. J. Conway. This locality is almost exactly halfway in a direct southwestwardly line between the Chicago area and Streator, La Salle County.

The latter, therefore, remains the point of greatest range extension in Illinois from the Chicago area where it was first observed. This is somewhat surprising in view of its rapid spread heretofore; but it may reflect lack of collecting and reporting rather than absence of the species in a wider area.

Intensive collecting of skippers in Illinois, particularly in the southern portion of the state, may well yield results of equal interest and significance to those presented in this paper. It is unfortunate that so many amateur collectors neglect this fascinating group as difficult, uninteresting, or both!

Specimens on which the records in this paper are based are in the collections of the Illinois Natural History Survey, Southern Illinois University, the Field Museum of Natural History, and the personal collection of Mr. Thomas Taylor, of Peoria, Illinois.

I am grateful to Mr. H. A. Freeman for the determinations which are ascribed to him herein.

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HESPERIA METEA LIFE HISTORY STUDIES (HESPERIIDAE)¹

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HESPERIA METEA SCUDDER RANGES WIDELY over the eastern half

of the United States. There is clinal graduation from typical *H. metea* found in the New England states to the much darker and larger *H. metea licinus* (Edwards) of eastern Texas. Specimens from the Ozark plateau region of Missouri and Arkansas are slightly smaller than *licinus* but otherwise compare well with that population. This is a univoltine species with imagines flying in any given region for a few weeks in the spring. The typical habitat in the Ozark region is found on dry, often rocky hillsides in direct proximity to woodland areas. Beard grass (*Andropogon gerardi* Vitm.), a characteristic plant of the Ozark flora, serves as the larval host. *H. metea* is one of the earliest native spring species, adults emerging with the flowering of red bud and wild plum trees. The wary males are found resting on bare patches of earth or visiting early flowers. Bird's-foot violet (*Viola pedata*) and wild strawberry (*Fragaria virginiana* var. *illinoensis*) are especially attractive. Females are not as wild and can be observed flying about the larval host plants where they settle near the base of the plants and crawl among the dried leaves and litter laying eggs. Since females fly a little later in the season they express some additional flower preferences and frequent wild larkspur (*Delphinium carolinianum*), wild hyacinth (*Camassia scilloides*), and *Verbena* species.

This species is the possessor of an interesting and unusually complicated life cycle. Females lay freely in captivity with or without the presence of *Andropogon*. During the first few instars the larvae are nocturnal in feeding habits: remaining hidden in their tents during daylight hours. In the later instars the larvae live deep within the base of the plants: actually tunneling below ground level. During the hot weather of late July, August, and early September the larvae spend long

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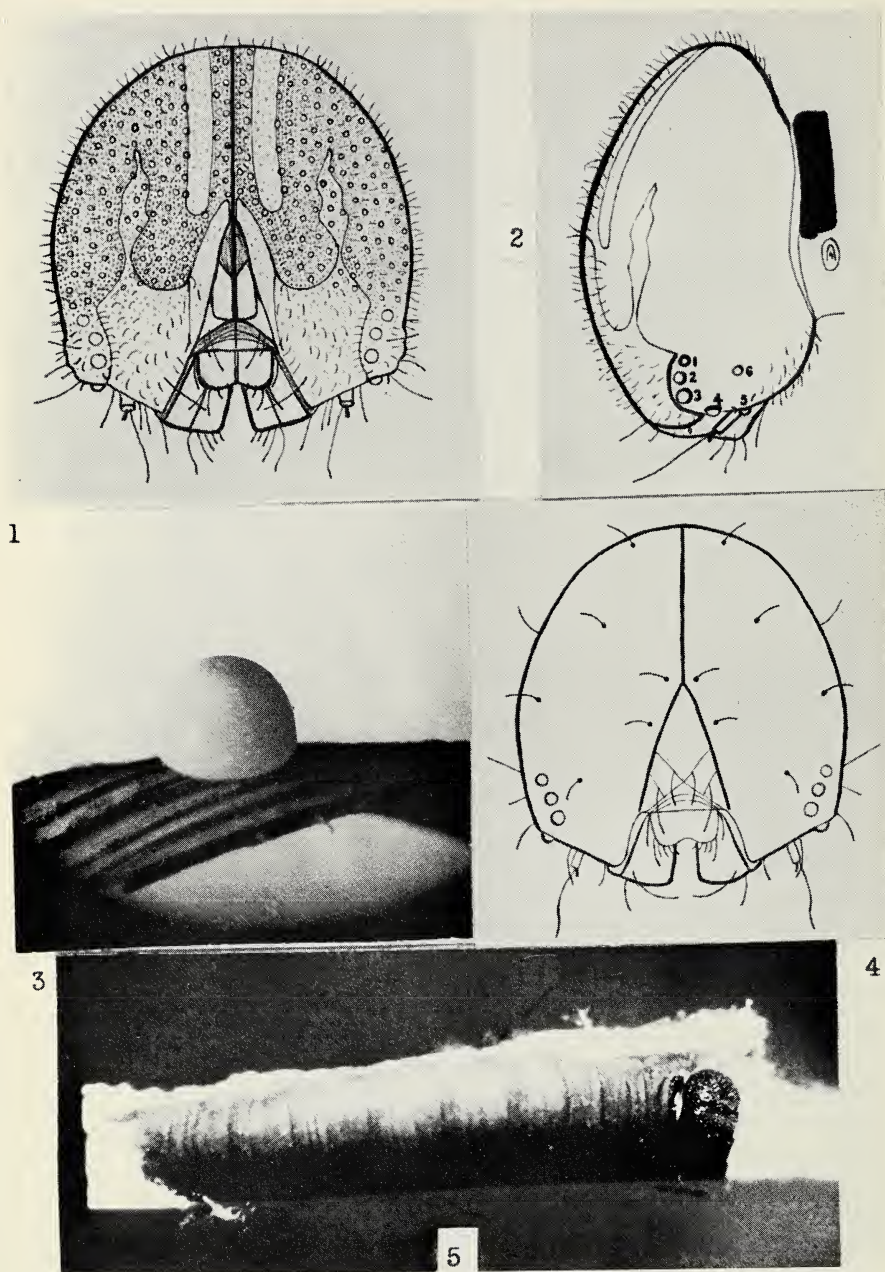


Fig. 1.—*Hesperia metea* Scudder, 1-2, Head of final instar larva, frontal and left lateral aspect. 3, Ovum. 4, Head of first instar larva, frontal aspect. 5, Mature larva.

periods in aestivation hidden deep within their tunnels. The larvae are fully developed when the first cold weather of fall arrives which provides the stimulus for hibernation. The hibernation chamber is constructed between two or more grass blades deep in the center of the grass plant. The chamber is thickly lined with silk and tightly sealed. Pupation supposedly occurs with the first warm days and rains of early spring. We have reared this pesky species from ova to hibernating larvae six different years but have yet to obtain a single pupa. We have tried numerous indoor and outdoor arrangements including enclosing entire growing plants in the garden with screen wire cages. *H. metea* does not occur in the Independence area and we have had no opportunity to attempt rearing in its native Ozark haunts. There may be edaphic problems involved since climatic conditions are essentially the same in both areas.

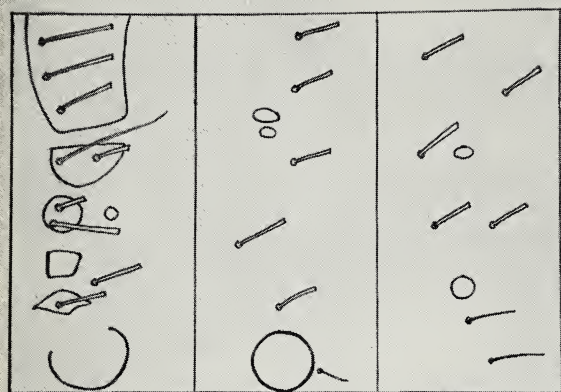
Many hours have been spent in the field during early spring looking for the "needle in the haystack." By carefully pulling apart the dried *Andropogon* clumps we have found pupae of *Atrytonopsis hianna* (Scudder), *Everes comyntas* (Godart), *Apantesis anna* Grote, and seven species of Noctuidae. At least a dozen *metea* hibernation chambers with the shriveled remains of their occupants have been found. This suggests that the natural mortality rate may be high during this dormant period. The following descriptions, minus the elusive pupa, are based upon six rearings from ova to hibernating larvae and many field observations conducted in the vicinity of Warsaw, Missouri, and Fayetteville, Arkansas. The illustrations were drawn by the junior author from specimens collected near Warsaw, Missouri during 1968 and 1969.

OVUM: Width 1.50mm, Height 1.25 mm. Creamy white, no visible markings. Eclosion in seven to eight days. Micropyle darkens on fifth day in fertile ova.

FIRST INSTAR LARVA: Head deep glossy purple, thinly covered with short pale setae. Prothoracic shield deep purplish black. Body white, unmarked, sparsely covered with white setae, some longer hairs on anal segment. The emerging larvae eat from one half to an entire egg shell. After eating the egg shell the larvae make a narrow open tent along a leaf edge a few inches from the tip. Small notches are eaten from one side of the grass blade for several inches up and down the leaf including the tent itself. After a few days of feeding the tent is enlarged and a greater amount of silk expended than for the initial structure. On the second day of feeding the body assumes a slight greenish tint. Stadium period: seven to nine days.



1

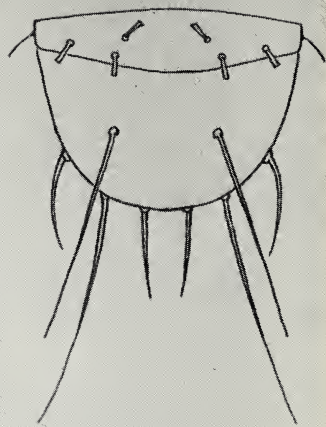


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Tii

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2



3

Fig. 2.—*Hesperia metea* Scudder, 1, Adults male and female, dorsal and ventral view. 2, Setae of first instar larva, prothorax, mesothorax and eighth abdominal segment, all in left lateral aspect. 3, Setae of suranal plate, dorsal aspect.

SECOND INSTAR LARVA: Head deep purplish black, granu-
lose, thickly covered with short white setae. Prothoracic shield
purplish black. Body pale greenish white, the three posterior
segments paler. Body thinly covered with short white setae,
some longer hairs curving back from anal segment. A few
partial tents are constructed during this instar but in most cases
the larvae hide at the base of the leaves in a fold of the leaf
when not feeding. On the last day they spin a silk covering and
molt within this protection. Stadium period: 19 to 21 days.

THIRD INSTAR LARVA: Head, prothoracic shield, and first
pair of thoracic legs reddish purple. Head thickly covered with
short pale setae, mandibles black. Two pale orange areas visible
low on front of head capsule between stemmata and laterofacial
suture lines. Face deeply cleft at midcranial inflection which is
black with narrow orange edging. Body pale creamy gray, in-
tersegmental folds pale yellow. Body thickly covered with
minute black setae. Anal spiracles marked by a black dot.
Stadium period: 10 to 12 days.

FOURTH INSTAR LARVA: Head deep reddish purple, deeply
cleft at midcranial inflection which is edged with deep orange.
A large orange area is present between the stemmata and
laterofacial suture lines. Thoracic legs black tipped. Body
creamy gray with tiny pale orange setae, intersegmental folds
pale orange yellow. First thoracic and two anal spiracles marked
by black dots. Prothoracic shield black. Stadium period: 10
to 12 days.

FIFTH INSTAR LARVA: Head deep reddish purple, granu-
lose, covered with short orange setae, mandibles and stemmata
black. Midcranial inflection edged by narrow orange lines, frons
pale cream color. A small orange spot is located on each side
between the stemmata and the laterofacial suture lines. Pro-
thorax white, conspicuous. Prothoracic shield shiny black.
First thoracic and anal spiracles marked with a large black dot,
a tiny black dot at other spiracles. Body grayish orange, ab-
dominal area paler, thickly covered dorsally with minute orange
setae, a few longer hairs on anal segment, intersegmental folds
paler. First two pair of thoracic legs deep purple, last pair
pale brown. Integument opaque with a leathery texture. Larvae
in this instar feed voraciously for about a week after which they
become restless and leave the host plant. After wandering about
for a day they begin spinning thinly lined silken tubes one to
two inches in length in the center of the host plants near ground
level. Very little is eaten for the next three weeks, only a few
notches here and there over the plants. Every few days the
larvae move to new spots and start a new tube. The larvae are

extremely nervous during this period. Even approaching the plants causes them to move uneasily and may have been the cause of frequent moves to new quarters. This aestivation period is apparently brought on by the dry midsummer weather. The size of the larvae during the last two weeks of this instar remains nearly constant. Larvae being reared outside were spurred to prepare for and enter the sixth instar after summer showers had fallen. Larvae being reared indoors were stimulated by repeated soakings of rainwater. Since the rainfall was the apparent factor governing the stadium period of this and the next (sixth) instar the duration time varied greatly: from 19 to 31 days in the fifth instar to a maximum of 51 days in one instance in the sixth instar. After the moisture stimulus a period of several days of heavy eating would begin followed by rapid molting and ingress into the next stadium period.

SIXTH INSTAR LARVA: Head deep brownish purple, granulose, mandibles deeper purple. Midcranial inflection bordered with bright orange lines. There is a duller orange area between the stemmata and laterofacial suture lines with a small extension rising vertically opposite the midcranial inflection. A small orange raised area is located directly posterior to the stemmata. Prothorax shiny white, prothoracic shield jet black. Body an unusual pinkish gray best described as grayish flesh, abdomen and prolegs pale flesh color, anal segment paler dorsally, almost translucent. First pair of thoracic legs black, posterior pair pale brown. Integument semi-transparent, dark areas inside body showing as blurred undulating spots. Heart line visible as a dark, pulsing middorsal line. Intersegmental folds dark pink, smooth in appearance. Small white setae visible over the body, more noticeable on anal segment. Aestivation occurs off and on during the sixth instar with the larvae retiring to their silken lined tubes deep within the base of the host plants. Sometimes several days elapse without any noticeable evidence that they have emerged. At other times the larvae become restless and wander about over the plants eating small notches here and there. The larvae require three days preparation before molting. Stadium period varies greatly and is seemingly dependent upon the arrival and amount of moisture received.

SEVENTH (FINAL) INSTAR LARVA: Length of mature larvae is 31 to 34 mm. Body grayish brown with slight lavender overcast, abdomen and prolegs slightly paler. Integument slightly translucent with a wrinkled appearance between intersegmental folds. Prothorax white, prothoracic shield and thoracic legs jet black. Spiracles marked by black dots. Head dark purple with orange lines paralleling midcranial inflection.

Orange lines parallel laterofacial suture lines and enter a paler cream colored area between the stemmata and laterofacial sutures, this pale area with an uneven vertical extension. A protruding orange area is located just posterior to the stemmata of which three is largest, two and four about equal in size, one and six equal and five the smallest. Stemmata positioned as in sketch of head capsule. Extent and intensity of head markings is variable with different specimens tending to become obscure near end of final instar. The illustrations of the head capsule markings are from specimens that have just entered the final instar when they are sharp and clear. The larvae are lethargic during the final instar. When disturbed they will curl into a tight ball and feign death, remaining thus for long periods of time, as long as 35 minutes by actual count. They feed leisurely during the day in the open, retiring to their silk lined tubes when not feeding. The final tube tent is constructed in the center of the plants, extending two or three inches into the base of the plant. The final instar larvae have two fluffy white areas of waxlike flakes beneath the posterior segments of the abdomen. In other cases where we have observed these wax flake patches on larvae the pupae were subsequently found coated with them (perhaps an excess moisture repellent since in at least one case, *Euphyes dion* Edwards, the pupae are occasionally submerged under water for lengthy periods). Stadium period quite variable, hibernation being stimulated by cool weather which occurs in late September in the Ozark region during normal years.

We wish to express our thanks to Dr. Leo J. Paulissen, Fayetteville, Arkansas for valuable field assistance. We are indebted to Dr. Alexander B. Klots, American Museum of Natural History and Dr. Howard V. Weems Jr., Florida State Dept. of Agriculture for reading the manuscript and offering valuable advice. We also owe our thanks to Dr. John R. Reeder, Yale University for plant determinations concerning this and other life history studies in progress.

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HABITAT — *Oeneis chryxus stanislaus* W. HOVANITZ

Shown here is the type locality for the race *Oeneis chryxus stanislaus* on the ridge at Sonora Pass, California, elevation 9,700 feet, late June, 1970. Both north and south from this point, the ground color of the wings becomes lighter, terminating in the disjunct race *Oeneis chryxus ivallda* along the crest of the Sierra Nevada. To the east in the Sweetwater Range, the color remains brown. *Oeneis chryxus ivallda* has the distinction of being separated into two parts, isolated from one another by this intrusion of "brown" genes.



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NOTICES

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THEORIES ON THE NATURE OF LIFE. Giovanni Blandino, S.J. Philosophical Library, N.Y.

INTRODUCTION TO ZOOLOGY. Theodore H. Savory. Philosophical Library, N.Y.

WANTED:

Brephidium exilis, *B. fea*, *B. isophthalma*. Life material and specimens for distribution study. Roy Jameson, 2429 Wordsworth, Houston, Texas 77025.

ARGYNNIS. Local and world wide, for world biogeographic study.

Also related forms under whatever name. William Hovanitz, 1160 W. Orange Grove Ave., Arcadia, California 91006.

IN PREPARATION:

BUTTERFLIES OF NORTH AMERICA. William Hovanitz. Illustrating in color all the species and races of butterflies of the Nearctic region. Will be the first book on butterflies to use the *New Systematics*, biogeographical and genetic approach to an understanding of this group of insects.

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